UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA



# GUM DISEASES OF CITRUS TREES IN CALIFORNIA

BY
HOWARD S. FAWCETT



BULLETIN No. 360
APRIL, 1923

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY, CALIFORNIA
1923

DAVID P. BARROWS, President of the University.

## EXPERIMENT STATION STAFF

### HEADS OF DIVISIONS

THOMAS FORSYTH HUNT, Dean.
EDWARD J. WICKSON, Horticulture (Emeritus).
——— ———, Director of Resident Instruction.
C. M. HARING, Veterinary Science, Director of Agricultural Experiment Station.
B. H. CROCHERON, Director of Agricultural Extension.
C. B. HUTCHISON, Plant Breeding, Director of the Branch of the College of Agriculture at Davis.
H. J. WEBBER, Sub-tropical Horticulture, Director of Citrus Experiment Station.
WILLIAM A. SETCHELL, Botany.
MYER E. JAFFA, Nutrition.
RALPH E. SMITH, Plant Pathology.
JOHN W. GILMORE, Agronomy.
CHARLES F. SHAW, Soil Technology.
JOHN W. GREGG, Landscape Gardening and Floriculture.
FREDERIC T. BIOLETTI, Viticulture and Fruit Products.
WARREN T. CLARKE, Agricultural Extension.
ERNEST B. BABCOCK, Genetics.
GORDON H. TRUE, Animal Husbandry.
WALTER MULFORD, Forestry.
JAMES T. BARRETT, Plant Pathology.
W. P. KELLEY, Agricultural Chemistry.
H. J. QUAYLE, Entomology
ELWOOD MEAD, Rural Institutions.
H. S. REED, Plant Physiology.
L. D. BATCHELOR, Orchard Management.
W. L. HOWARD, Pomology.
*FRANK ADAMS, Irrigation Investigations.
C. L. ROADHOUSE, Dairy Industry.
R. L. ADAMS, Farm Management.
W. B. HERMS, Entomology and Parasitology.
JOHN E. DOUGHERTY, Poultry Husbandry.
D. R. HOAGLAND, Plant Nutrition.
G. H. HART, Veterinary Science.
L. J. FLETCHER, Agricultural Engineering.
EDWIN C. VOORHIES, Assistant to the Dean.

### DIVISION OF PLANT PATHOLOGY

J. T. BARRETT
H. S. FAWCETT
E. T. BARTHOLOMEW
C. O. SMITH

* In coöperation with Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture.

# GUM DISEASES OF CITRUS TREES IN CALIFORNIA*

BY

HOWARD S. FAWCETT

## CONTENTS



* Paper No. 92, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

## INTRODUCTION

The aim of this bulletin is to bring together the information now at hand regarding the so-called gum diseases of citrus and the various minor forms of gumming in citrus trees under California conditions. Special emphasis is here given to contributing conditions and to methods of prevention and treatment. A considerable amount of investigational data not heretofore published is included. The results of investigations in other phases of these diseases are being published in the Journal of Agricultural Research. These latter phases will therefore receive only brief treatment here in order to avoid undue duplication. It is necessary, however, to duplicate in part the descriptions of the diseases and a small amount of other data.

Previous investigators had come to the conclusion that all gum diseases of citrus trees in California originated independently of micro-organisms.[1] It was held that these diseases were largely autogenous in their nature, and frequently induced through the effects of certain climatic or soil conditions alone. It now appears evident that these environmental conditions cannot by themselves initiate the severe forms of gummosis in citrus earlier attributed to them, although certain factors are found to play (as they do in most parasitic diseases) an important role as contributing conditions which favor infection and invasion of the host by the causal parasites.

The investigational work on which the greater part of this bulletin is based was begun in February, 1912, under the direction of the State Commission of Horticulture and continued after October, 1913, at the Citrus Experiment Station of the University of California. Acknowledgment of the assistance rendered during this investigation has been given elsewhere.[2]

The names of species and varieties of Citrus will be used in accordance with Swingle[3] as follows: common lemon, *Citrus limonia* Osbeck; rough lemon, a horticultural variety of *C. limonia* Osbeck; sweet orange, *C. sinensis* Osbeck; sour orange, *C. grandis* Osbeck; citron, *C. medica* Linn.; trifoliate orange, *Poncirus trifoliata* Raf. The word lemon, when used alone will refer to the common lemon, and the word orange to the sweet orange.

---

[1] Smith, R. E., and Butler, O. Gum disease of citrus trees in California. Calif. Agr. Exp. Sta. Bull. 200, pp. 235–272, 1908.

[2] Fawcett, H. S., Two fungi as casual agents in gummosis of lemon trees in California. Monthly Bull. Calif. State Comm. of Horticulture, vol. 2, pp. 601–617, 1913.

[3] Swingle, W. T., "Citrus," *in* Bailey, L. H., Standard Cyclopedia of Horticulture, vol. 2, pp. 270–785, New York, 1914.

## PYTHIACYSTIS (BROWN ROT) GUMMOSIS

### HISTORY

A destructive form of gum disease similar to Pythiacystis gummosis first attracted serious attention in the Azores about 1834. A similar gum disease appeared in Italy as early as 1863; in Portugal, 1865; in Australia, 1867; in Spain, 1871; in the United States, 1865; and in most other citrus regions before the year 1890. See accounts and references by Savastano[4] Swingle and Webber,[5] Butler[6] and Fawcett.[7]

In the early history of citrus growing in California there appears to be no record of the occurrence of gum diseases until about 1875.[8] Not long afterwards they became an important hindrance to commercial citrus culture, as is evidenced by the horticultural literature of the time.

A committee of citrus growers appointed to examine the condition of citrus orchards, stated in 1878[9] that at that time few localities were free from gum disease, which this committee believed was caused by excessive irrigation and unsuitable cultivation. The orchards most heavily flooded with irrigation water, especially on heavy soils, were found worst affected. The application of manure immediately around the trees was also reported as tending to promote the disease. Lemon roots were found to be more susceptible than orange roots, and in a discussion which followed this report much objection is expressed to lemon and Chinese lemon stock as compared with sweet orange. Light soils were thought by many to be better adapted than heavy soils for orange culture since orchards on light soils were healthy while those on heavy soils were rapidly dying out, presumably from gum disease.

Irrigation by flooding was a common practice at that time and later[10] it was stated as a settled fact that the lemon (on lemon roots) is peculiarly sensitive to moisture and easily begins to rot if water is

[4] "Gommosi degli agrumi," *in* Patologia arborea applicata, bp. 127–141. Napoli, 1910.

[5] The principal diseases of citrus fruits in Florida. U. S. Dept. Agr. Div. Veg. Phys. & Path. Bull. 8, pp. 1–42, 1896.

[6] A Study on Gummosis of Prunus and Citrus, Ann. Bot., vol. 25, pp. 107–153, 1911.

[7] Gummosis of Citrus, Jour. of Agr. Research. (*In press.*)

[8] Mills, J. W., Citrus fruit culture. Calif. Agr. Exp. Station, Bull. 138, pp. 1–46, 1902.

[9] Southern Calif. Horticulturist, vol. 1, p. 115, Jan., 1878.

[10] Southern California Horticulturist, vol. 1, pp. 314–315, July, 1878.

left standing around it. In the following year the statement was made in the same publication[11] that gum disease is induced by midsummer irrigation and that lemon trees on their own roots were dying rapidly. In 1882 a leading nurseryman[12] regarded gum disease as the only citrus trouble of importance.

Of the four citrus stocks commonly used at that time (sweet orange, lemon, lime and citron) the lemon and the lime were stated by Gary to be the most fatally affected with this disease. He advises the use of the sweet-orange stock but says nothing of the sour orange which was introduced at a later date. Gary's description of the disease and his reference to the differences in susceptibility of varieties indicate that the type of disease spoken of was Pythiacystis gummosis. Because of the susceptibility of the lemon the growers gradually discovered that other stocks must be used. The universal verdict according to Holt[13] in 1892 was that lemons should not be grown on their own roots.

Sweet-orange stock though much less susceptible than lemon was also frequently affected with gummosis. This fact drew attention to the sour-orange stock which had been used successfully in southern Europe and in Florida to replace trees affected with mal di gomma. This resistant stock only gradually came into use as a preventive of gum disease in California. Cutter[14] in 1892 stated that his attention was called first to the value of the sour-orange as superior to sweet in its resistance to gum disease in 1885. The following year the firm of Twogood, Edwards and Cutter of Riverside, received the first shipment of sour-orange trees from Florida for commercial purposes; although a few trees had been grown from Florida seeds for test by others before this time.

In the light of our present knowledge of varietal susceptibility of citrus to gum diseases and of the part played by heavy soils and by excessive irrigation (especially flooding on heavy soils), the failure in growth on lemon stocks, and the dying of trees on heavy soils, but not on lighter soils would now appear to have been due to the presence and attack of gum disease organisms, especially *Pythiacystis citropththora* Smith and Smith.

The early discontinuance of the use of lemon, lime and citron as stocks, and the adoption of the orange as a general stock for all

---

[11] Southern Calif. Hort., vol. 2, pp. 83–86, March, 1879.

[12] Gary, Thomas A., Orange culture in California. Pacific Rural Press, pp. 81–82, San Francisco, 1882.

[13] Holt, L. M., "Lemon culture for profit," Proc. Calif. Pomological Soc., 1892.

[14] Cutter, J. E., Proc. Calif. Pom. Soc., 1892.

varieties appears to have been largely brought about by this one disease. Sour-orange stocks were introduced from Florida later, as previously indicated, for the purpose of combating this disease on heavy soils, but this stock has not become of widespread use in California until recent years.

## SYMPTOMS

Pythiacystis or brown-rot gummosis with its associated rot of the fruit[15] is probably the most widespread and destructive of the citrus gum diseases. On the lemon (the most susceptible variety) patches of bark on the trunk are killed and often large quantities of gum are exuded (figs. 1 and 2*a*.) Infection usually starts at the base of the trunk or on the crown roots and works rapidly both upward and laterally. The bark is killed (not as in cases of Psorosis and shell-bark, merely in the outer cortical layers) but entirely through to the wood, thus including the cambium. A thin layer of wood tissue only about 1/12 of an inch thick is visibly affected unless secondary organisms enter. The bark above the soil is not softened as it is in the early stages of Botrytis gummosis but remains firm and intact until drying causes it to shrink and crack longitudinally (fig. 2*b*). Below the surface of the soil secondary organisms frequently set up fermentation and moist decay. On the bark of old orange trees and other partially resistant varieties often the progress of the disease is soon arrested and the lesions tend to become self-limited. The loss of large patches of bark is followed by a gradual yellowing and dropping of leaves on the branches leading out from the portion of the trunk affected.

Although these are the main characteristics of the disease as seen on superficial examination, there are many special features which appear when more careful study is given to its development under various conditions. In the earlier stages of the disease the exuding gum is usually the only external symptom (fig. 2*a*). By lightly scraping the bark at this time the margin between the sound and invaded tissue is shown indefinitely, only by the gradual shading of the normal green color into a drab. The bark is not softened but remains firm and only after a considerable time does it shrink and crack longitudinally (fig. 2*b*).

On healthy, rapidly growing lemon trees the area of killed and darkened bark, which is elliptical or irregular in outline, is usually 5 to 10 inches in vertical length and half that in width, when the gum

15 Smith, R. E. and others, The Brown Rot of the Lemon. Calif. Agr. Exp. Sta. Bull. 190, 70 pages, 1907.

first becomes apparent. By that time the fungus has invaded the the bark at this time will show that the outer margin of the invaded zone in the inner tissues is about coëxtensive with that seen on the surface. The upward and downward extension from the point of infection is usually many times greater than the lateral extension.

In an irregular zone or band surrounding an actively invaded area, the cambium layer shows an influence extending from the margins of the dead bark. There is a production of clear, watery gum which seems to originate in the region of the embryonic wood among the live cells without any apparent fermentation or decay. This region, not yet darkened, outside the invaded portion, will be spoken of in this paper as the "outer gummous zone" (fig. 3*b*). It may in time extend considerable distances upward and downward and small distances laterally from the margin of the invaded zone (fig. 3*b*). It has been traced for 2 and 3 feet upward. The extent of this outer gummous zone varies with the age and rapidity of development of the disease lesion, the condition of the tree, etc.

The inner surface of the bark in the invaded zone in a lesion of considerable size varies in color from mineral brown to burnt amber or fawn[15] and the same discolorations will be found on the surface of the wood just at or beneath the cambium (fig. 3*b*). The discoloration does not extend far (usually only 1/12 to 1/5 of an inch) into the woody layers. The cambium region in the gummous zone is chamois to yellow ochre in color, gradually fading at the margins into the normal color of the sound woody surface.

Frequently, when the bark is irregular in contour, gum pockets 1 to 2 inches in length will be formed. The gum accumulates near the cambium and by pressure separates the bark from the wood at certain places, forming definite pockets. The pressure is usually relieved by a break in the bark before the pockets become large. A few deeper gum pockets of considerable size have also been found, tissue usually for a period of from 2 to 4 months. The removal of situated in the outer gummous zone beneath layers of wood 1/8 to 1/4 of an inch in thickness, showing accumulations of gum under pressure. The gum, which is watery and clear when first formed, hardens as it comes to the surface, apparently through loss of water, and finally becomes brittle. On the surface the hardened gum is usually mahogany to chestnut in color.[16] The gum accumulates on the surface in long narrow ridges (figs. 1 and 2*a*) or in oval masses, or runs down and collects in masses on the soil, according to the rapidity of its

[16] Ridgway, Robert, Color standards and color nomenclature, 43 pp., Washington, D. C., 1912.

Fig. 1.—Pythiacystis or brown-rot gummosis on lemon trunk. The tree is completely girdled the dead bark resulting from several infections starting near the soil surface. Ridges of exuded gum are characteristic.

formation and the dryness of the air. During periods of heavy dews and rains it gradually dissolves and disappears. The invading hyphae frequently die out rapidly behind the marginal fringe of advance, and quite often they die out completely over a part or all of this outer margin, so that the progress of the disease is checked or entirely arrested. Such cases are often found among trees having some power of resistance, especially among orange and pomelo trees; or where the weather conditions subsequent to infection become unfavorable to the parasite.

In trees on which the disease has been present for a long time, the dead bark over the invaded portions dries, shrinks and cracks. The larger cracks are mostly vertical, with smaller horizontal cracks (fig. 2*b*). A thin layer of the wood immediately under the invaded bark will usually be found to be infiltrated with hardened reddish-brown gum which protects the under layers from rapid drying and to a considerable extent against the entrance of wood rotting fungi.

On old sweet-orange trees, the invaded areas are usually less extensive and more restricted laterally than on the common lemon. There is usually less gum than on the lemon. In the orange there is a greater tendency for the invading fungus to die out and for the invaded area to become self-limited than in the lemon. Frequently the invaded areas on old sweet-orange trunks extend upward from the soil surface as narrow tongues of killed bark. On younger orange trees and frequently on older ones growing vigorously on heavy clay soils the disease may assume much the same characteristics as it does on the common lemon.

## INVESTIGATIONS INTO THE NATURE AND CAUSE OF THE DISEASE

Investigations begun in 1912 by the author[17] have led to the discovery that the disease is infectious and that the casual agent is a soil inhabiting "water mold," *Pythiacystis citrophthora,* the same fungus which was previously described as causing brown rot of lemon fruits.[18] The relation of this fungus to the disease was discovered as a result of a series of experiments as follows:

1. Inoculation into sound trees with bits of diseased tissue transmitted the disease with all its characteristic symptoms (fig. 2). It was found, however, that only the diseased tissue from the marginal

---

[17] Fawcett, H. S., Two Fungi as Casual Agents in Gummosis of Lemon Trees in California. Month. Bull. Calif. State Comm. of Hort., vol. 2, pp. 601–617, 1913.

[18] Smith, R. E. and others, The Brown Rot of the Lemon, Calif. Agr. Exp. Sta. Bull. 190, 1917.

fringe of the killed bark of active lesions was capable of transmitting the disease. Tissue from places back of this margin toward the center of large lesions or from the outer gummous zone was incapable of inducing gummosis.

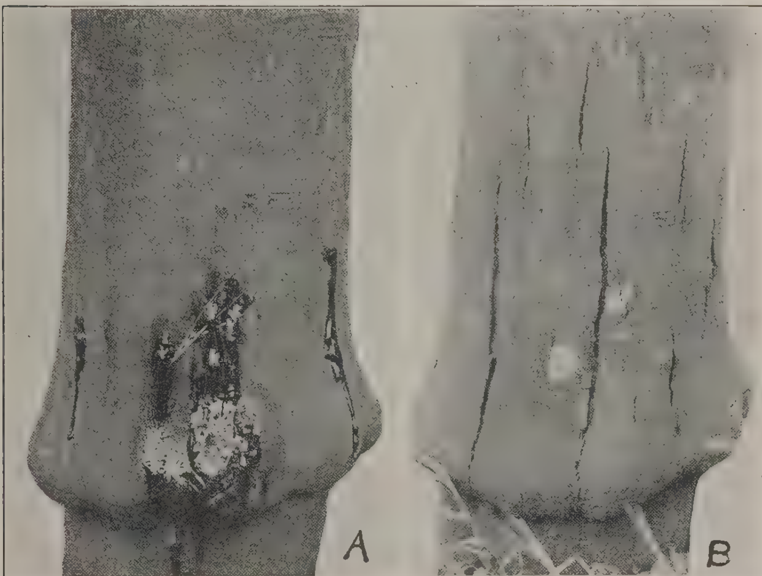


Fig. 2.—Pythiacystis or brown-rot gummosis on lemon tree. Produced by inoculation with diseased bark tissue.

(*a*) Tree inoculated February 27, 1912 and photographed April 24, 1912. The large amount of exuded gum indicates the rapid development of a gummosis lesion. A majority of the trees in this same orchard had the same over growths at the union of stock and scion as observed in this illustration.

(*b*) Same view as (*a*) on May 24, 1913, 15 months after inoculation. The gum first formed has been dissolved by winter rains, and the dead bark has dried and shrunken. Gum was exuding (farther around) at this time.

2. Culture tests made from pieces of bark from various places within and beyond the killed portion of the lesions revealed the presence of *Pythiacystis citrophthora* but usually only at the marginal fringe of what was subsequently called the invaded zone. This fungus usually could not be isolated from the central portion of the invaded zone and it was never found well out of the outer gummous zone. Isolations of this fungus were made at least 109 times from gummosis trees representing 30 different orchards in 10 different counties of California extending from San Diego on the south to Butte county on the north. It was isolated also from one locality in Arizona.

3. Inoculations were made into bark of sound trees with pure cultures of this fungus and the disease was induced with all its characteristic symptoms (figs. 3 and 4*a*). Many repetitions gave the same results. Inoculations with large numbers of other fungi and bacteria found in the older portions of the invaded zone failed to cause the disease. The reason for the fact that only diseased tissue from the marginal fringe of the invaded zone was capable of transmitting the disease was now revealed. In this portion only, does the causal organism *Pythiacystis citrophthora* usually remain alive.

4. The same fungus was re-isolated 40 different times from 20 of the cases of gummosis produced by inoculation and again found to be alive only at the outer margin of the invaded zones, just as in the naturally occurring cases previously mentioned. The time elapsing between inoculation and re-isolation was from 1 to 12 months in different tests, and the fungus was recovered at distances of 20 inches or more from the original point of inoculation. One strain of this fungus isolated from a diseased tree at Whittier was inoculated into and re-isolated from three different trees in succession during a period of 3 years from 1912 to 1915. During this time the fungus lived in the bark of the three trees for periods of 5, 11, and 6 months respectively and between these periods in cultures for 2, 2, and 10 months respectively. Transfers from the original culture which was kept alive for more than 8 years on cornmeal agar medium were capable of producing brown rot of lemon fruits when tested in 1921.

5. Inoculations were made also with bits of lemon fruits affected with brown rot and with the fungus *Pythiacystis citrophthora* isolated from diseased fruits, with the same results as those obtained by the use of bits of diseased bark or cultures isolated therefrom. This experiment served to show that the fungus previously known to cause brown rot of lemon fruits and the one capable of inducing this type of gummosis were identical. The detailed experiments on which these statements are based are being published in the Journal of Agricultural Research.

## RESISTANCE OF DIFFERENT SPECIES AND VARIETIES

Among the citrus species and varieties that have been tested the common lemon has the lowest resistance to Pythiacystis gummosis, and the sour orange the highest. The sour orange usually is so resistant to *Pythiacystis* attack that even when the most favorable conditions are given by inoculation in wounds, there is only a slight gumming with rapid healing of the wounded tissue and with total failure to produce a diseased lesion. The sour orange is also highly resistant to all other infectious gum diseases of importance. Mere

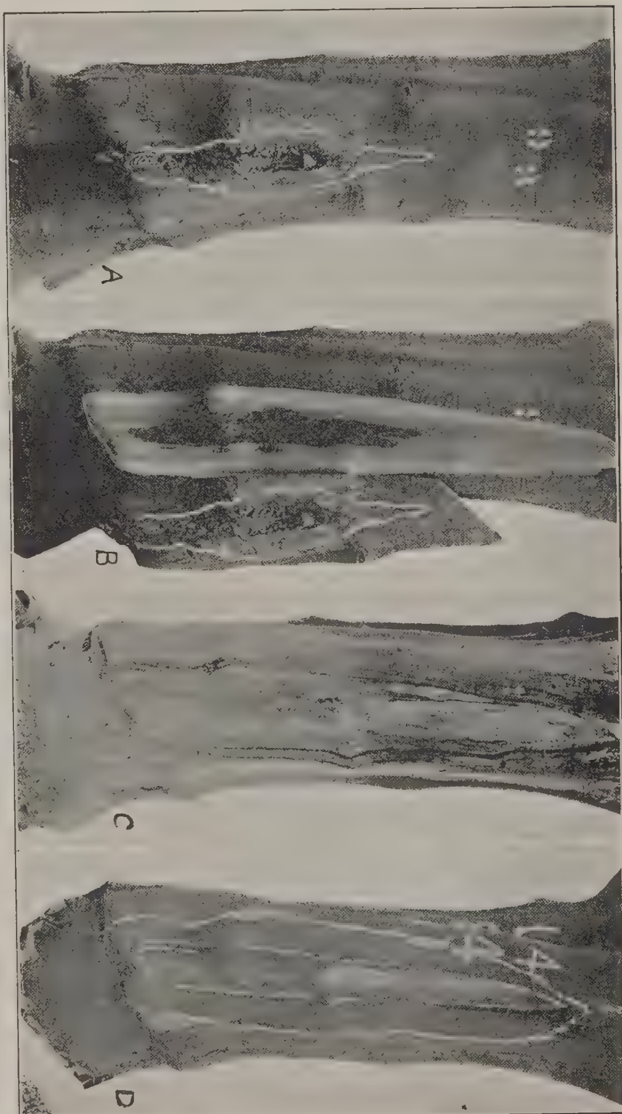


Fig. 3.—Pythiacystis or brown-rot gummosis on lemon tree. Innoculated November 23, 1912, with pure culture of *Pythiacystis citrophthora.*

(*a*) Extent of invaded portion (inside of chalk line) and gum formation on June 6, 1913. The fungus was isolated from several places near chalk line on this date. (*b*) Same tree after bark was cut, showing invaded zone (black) and a part of the outer gummous zone, which extended upward and downward under live bark. (*c*) Same tree in September, 1914, showing a new bark pushing in over wound. (*d*) Same tree in June, 1920, showing increase in new bark covering edges of original wound.

gum formation, however, may be induced by suitable stimuli in sour orange as well as other species and varieties. Of the forms which have been most used for stocks in California, the trifoliate orange probably stands next to the sour orange in resistance and the sweet orange next to the common lemon in susceptibility, with the pomelo and the rough lemon standing between these two. Because these stocks are grown from seed there is a possibility of variation in resistance within each variety due to differences between strains and observations have suggested that such variation actually exists. The following observations indicate the relative resistance of some of the common varieties.

A block of 5,000 sweet-orange seedlings about two and one-half years old, growing in nursery rows on medium heavy clay loam soil, had been planted adjacent to a block of 15,000 sour-orange seedlings of the same age and receiving the same care. All the trees had been irrigated rather frequently and heavily. On October 21, 1914 four representative rows of sweet-orange trees showed the following percentage of infection:

| Row | Number of trees in row | Number of affected trees | Percentage affected |
|---|---|---|---|
| 1 | 222 | 52 | 23 |
| 2 | 213 | 73 | 34 |
| 3 | 212 | 63 | 29 |
| 4 | 180 | 53 | 29 |
| Total | 827 | 241 | Average 29 |

On some trees only a small lesion was evident with much gum exuding, on others the bark was killed to a distance of 6 to 12 inches above the soil, with an abundance of gum, and still other trees were dead. Some trees showed a strong tendency to form ridges of callous tissue along the edges of the dead strips of bark. A thorough search in the block of sour-orange trees failed to reveal a single affected tree.

Differences in resistance are indicated further by an estimate made by W. M. Mertz, in a nursery of citrus seedlings about two years old, growing at the Citrus Experiment Station. The following is the percentage of gum disease (probably Pythiacystis gummosis) which was recorded.

| Species | Number of trees | Per cent with gummosis |
|---|---|---|
| Citrus Aurantium (sour orange) | 1000 | 0.3 |
| Poncirus trifoliata (trifoliate orange) | 1000 | 1.0 |
| Citrus grandis (pomelo) | 1000 | 2.5 |
| Citrus sinensis (sweet orange) | 2000 | 10.00 |

## CONDITIONS FACILITATING INFECTION AND DEVELOPMENT OF THE DISEASE

A study of the external conditions under which Pythiacystis gummosis is most likely to become severe, taken in conjunction with experiments with the fungus, indicates that the important factors are: (1) abundant moisture in the soil in contact with the bark over a sufficiently long period, (2) favorable soil and air temperature, and (3) wounds or other injuries to the bark.

Injuries, however, although aids to infection, are not necessary if the two first-named conditions are simultaneously fulfilled. Injuries, especially below the soil surface, aside from inducing infection more readily when the conditions of moisture and temperature are suitable, may even aid in bringing about infection where the soil moisture is not excessive by conveying the organism into the moist inner bark tissue where penetration can start without the addition of further moisture. Wounds or injuries, therefore, while not absolutely necessary for the entrance of the parasite when sufficient moisture is present are probably the only means of entrance when the moisture content of the soil immediately in contact with the bark surfaces is not favorable for infection.

*Moisture.*—The severe form of Pythiacystis gummosis is most frequently found in California on lemon trees where they are budded low on sweet-orange stocks which are growing on heavy soils and is especially prevalent in the coastal sections. In the light of what has been stated previously it is readily seen why this should be true. Heavy clay soils, being much more retentive of moisture than lighter, more open soils, furnish the means by which water films may remain adjacent to the bark for periods of time sufficient to permit infection by the fungous parasite.

The great prevalence of fogs, and the comparatively slight fluctuations of temperature in the coastal sections also decrease the rate of evaporation in the soil adjacent to the trees that has become excessively wet during irrigation or rain. In the interior valleys even the same type of soil usually drys out more quickly after irrigations and rains. If the drying out is rapid there is not sufficient time for infection; if drying is slow, however, the time may be sufficient for the penetration of the fungous hyphae. The effect of a low bud union has already been discussed. The lemon bark above the union may be infected directly when the fungous parasite has communication directly with it through excessively moist soil or by splashing of raindrops, especially when wounds are present. High budded lemon trees have

less chance of contracting the disease. If budded high on sweet-orange stocks they will have somewhat more chance to escape, because this stock is somewhat more resistant than lemon; it is nevertheless susceptible to infection, especially under conditions highly favorable to the disease. If budded high on sour-orange stock, however, there is practically no danger of the disease even under bad water conditions, because of the great resistance of the sour-orange stock.

*Temperature.*—Within certain limits temperature appears to be another important factor, especially in the growth of the fungus and its formation of spores and in the infection of the host as a result of the germination of these spores. As has been previously shown,[19] a temperatue somewhere near 25°C. (77°F.) appears to be about the optimum for a sustained growth of the fungous hyphae in cultures, and very little growth takes place above 30°C. (86°F.). If as seems probable similar relations hold for the growth of the fungus in the bark, we have an explanation of the fact that the disease progresses slowly during hot periods, and also for the fact that its progress is sometimes completely checked, the fungus being killed out in many instances. This is especially true in the interior valleys, in the case of parts of lesions entirely above the soil surface. Here the temperature of the bark frequently becomes many degrees above the death point of the fungus. Recent experiments[20] have shown that a temperature of 115°F. for one minute is sufficient to kill the spores of this fungus on infected fruits and temperatures much lower than this for greater lengths of time will undoubtedly have the same effect.

In line with this possibility is the observation that the rapid enlargement of invaded areas usually continues much later in the year or may proceed throughout the whole year in the cooler coastal sections, while the activity and progress of the disease are usually limited to the winter, spring and early summer in the hotter interior sections. The following experiment may be given as having a bearing on the influence of temperature.

On September 10, 1914, at Whittier, inoculation was made by inserting a bit of mycelium of *P. citrophthora* into a cut in the trunk of a five-year-old lemon tree. On October 9, about one month later, the bark was killed vertically 6 inches above and 6 inches below the ino ulated cut and about 3 inches horizontally at the widest place, with abundant gum on the surface. On cutting off the bark at this time it was noted that there were concentric rings at the cambium layer, corresponding in number approximately to the number of days

[19] Fawcett, H. S., The temperature relations of growth in certain parasitic fungi., Univ. Calif. Publ. Agr. Sci., vol. 4, pp. 183–232, 1921.

[20] Fawcett, H. S., Calif. Citrograph, vol. 7, pp. 233 and 254, May, 1922.

from time of inoculation and probably due to differences in rates of advance during night and day. The rate of advance downward and upward averaged about ⅕ of an inch per day. The average daily mean temperature at the nearest weather bureau station (Los Angeles) was about 19.5°C. (67°F.) with an average fluctuation of about 5°C. (16°F.). It is of interest that the maintained temperatue at which *P. citrophthora* advanced at approximately this rate in culture media was 21°C. (71°F.) (See table 1, Univ. Calif. Publ. Agr. Sci., vol. 4, p. 201). Further investigation is needed to determine the relation of temperature to the rapidity of advance of the fungus in invaded tissue.

*Other Conditions.*—A further condition which contributes to the chance of infection in the orchard is that of deep planting, or the accumulation of soil next to the trunk of the trees. Under these conditions there is greater surface of the bark in contact with the soil, and the bud union, if low, becomes buried. The bark over the union between stock and scion is usually especially susceptible to infection, probably because of frequent irregularities of growth, suckering, etc. The practice of loosening the soil by digging about the base of the tree, if no injuries are produced, probably helps to prevent infection by hastening the drying out of the soil. This practice may, on the other hand, if carelessly performed, result in injuries to the bark and aid in the entrance of the organism or actually introduce it into the inner bark tissues on bits of soil. Any agencies such as gophers, field mice, or rabbits, or tools used in orchard operations that produce injuries to the bark, may contribute to the ease of infection by the fungus parasite. Infection, however, appears to take place frequently through the sound uninjured bark.

The following is a concrete example of a set of conditions that resulted in a serious outbreak in a 5-acre 6-year-old lemon orchard at Whittier in 1914, on medium heavy clay soil.

The season had been one of unusually heavy rainfall. A volunteer crop of barley was cut while green in March and thrown around the trees in contact with their trunks. This operation was followed by heavy rains and cloudy days. The following May 90 trees with brown-rot gummosis in various stages were discovered. The lesions appeared to have started at various places below and above the surface of the soil. Some of those above the surface had started at places where water sprouts had been broken off, but many appeared to have started in sound, uninjured bark. The barley piled around the trunks had undoubtedly aided in retaining films of water for a sufficient time to permit germination of the spores and the penetration of the hyphae.

All the diseased trees were successfully treated under the author's directions and the results will be discussed under the heading of control.

## FUSARIUM AS A SECONDARY AID IN THE DEVELOPMENT OF PYTHIACYSTIS GUMMOSIS

During the examination of a large number of naturally occurring cases of Phythiacystis gummosis it was noticed that a species of Fusarium frequently accompanied and was closely associated with *P. citrophthora* in the diseased tissue. The question arose as to whether the Fusarium played any part in the development or the severity of the disease.

Fusarium has been mentioned frequently in the literature as having some possible relation to certain types of gum disease. Briosi[21] and McAlpin[22] concluded that *Fusarium limoni* Briosi played an important part in mal di gomma in Italy and in Australia. Earle and Rogers,[23] though not able to produce gummosis by inoculation with Fusarium, believed that under certain conditions it was probably a factor in a certain type of gum disease in Cuba. The present writer also had previously found species of Fusarium repeatedly associated with mal di gomma or footrot in Florida, but inoculations with them had given negative results.

Although the experiments made with this question in mind have been too few as yet to allow definite conclusions to be drawn, certain results have indicated that the severity of the disease is slightly increased by adding Fusarium along with *Pythiacystis citrophthora* at the time of inoculation. The characteristics of the disease, however, were the same as when the *Pythiacystis* was inserted alone, while inoculation with Fusarium alone failed to produce this type of gummosis. Fusarium inoculations caused only a slight killing of a narrow layer of tissue along the cut without gumming and later resulted in a cracking of outer layers of bark around the cut. Otherwise the effect was not different in either case from that produced in the inoculated cuts used as checks on the same trees. The details of this experiment will be found elsewhere in this article.

---

21 Briosi, G., Intorno al mal di gomma degli agrumi (*Fusisporium limoni*, Briosi). Atti R. Acad. Lincei, Roma, ser. 3a, vol. 2; Memoria della classe di science fisiche etc., pp. 485–496, 1878.

22 McAlpine, D., Fungus diseases of citrus trees in Australia and their treatment, Melbourne, p. 132, 1899.

23 Earle, F. S. and Rogers, J. M., "Citrus diseases at San Pedro in 1915," *in* San Pedro, Isle of Pines, Citrus Path. Lab., Ann. Report 1, pp. 36–38, 1915.

## METHODS OF CONTROL

*Prevention.*—The causative fungus usually infects the bark at or below the surface of the soil. The roots of a susceptible variety are more resistant than the bark of the trunk. As pointed out above, some of the principal conditions of infection are: (1) excessive wet soil in contact with the trunk, as a result of improper irrigation and drainage, or long periods of continuous rains; (2) deep planting, or soil piled up around the trunk, especially when it is highly retentive of moisture; (3) injuries to the bark at the base of the tree, especially in wet weather.

The methods which have been found effective and are now in common use in preventing infection brought about by these conditions, are as follows:

The soil is pulled back from the base of the tree to expose the top of the first main roots and is left in a circular ridge to exclude irrigation water from the depression next to the trunk. If the depression occasionally becomes filled up with water, the resulting condition is usually not so serious as when the soil is against the bark, because the water after a rain soon percolates into the soil. Under usual weather conditions in California, with most citrus soils, the length of time that water would stand in such a depression is not sufficient to produce infection.

This pulling away of the soil is most important on the heavier clay soils, while on looser sandy soils this practice is not so necessary.

As an additional means of prevention the bark at the base of the trunk is painted with Bordeaux paste or other non-injurious fungicide after pulling the soil away.

*Experiments in Prevention.*—The following experiment on 15-year-old lemon trees at Chula Vista has been reported by Prizer.[24] The trees had low bud unions and the soil (a heavy "adobe") had not been carefully pulled back from the base. Ten per cent of the trees had new lesions on the trunk the year before. Thirty-six per cent of the trees had already been killed by the disease and were missing. The trunks, in two rows containing 81 trees, were painted with Bordeaux paste in the fall of 1913, and two other rows next to them containing 72 trees were left unpainted as controls. During the next summer there were 6.9 per cent of the unpainted trees affected with new lesions as compared with 1.2 per cent of the painted.

[24] Prizer, J. A., Month. Bull. Calif. State Comm. of Hort., vol. 4, pp. 7–19, 1915.

In 1913 and 1914 the San Diego Fruit Company, Chula Vista, California, instituted methods of prevention. Greater care was used in keeping the soil away from the base of the tree. During the summer and fall of 1913 most of the trunks of the trees were painted with Bordeaux. The following table shows the number of new cases in 6 orchards on which a three-year record was available.

| Acres in orchard | Number of trees newly infected | | |
|---|---|---|---|
| | 1912 | 1913 | 1914 |
| 10 | 20 | 7 | 0 |
| 30 | 9 | 25 | 5 |
| 30 | 19 | 5 | 5 |
| 10 | 11 | 4 | 0 |
| 20 | 43 | 43 | 4 |
| 10 | 21 | 5 | 2 |
| Total 110 | 123 | 89 | 16 |

The marked decrease in the number of new cases of gummosis from 1912 to 1914 will be noted. The total number, 123 in 1912, had decreased to 16 or about one-eighth as many in 1914.

At Santa Paula records of trees affected with gummosis during 1912 to 1914 inclusive, were preventive treatment somewhat similar to that carried out at Chula Vista was applied, show a similar decrease or falling off in new cases.* These records include both Botrytis gummosis and pythiacystis gummosis and possibly some other forms of gummosis since these were not separated. The following table of various blocks gives the numbers of the trees with new lesions.

TABLE 1

| Block | Number of trees in block | Number of trees newly infected | | |
|---|---|---|---|---|
| | | 1912 | 1913 | 1914 |
| A | 1213 | 33 | 14 | 4 |
| B | 2588 | 150 | 132 | 5 |
| C | 1340 | 124 | 28 | 4 |
| D | 685 | 29 | 9 | 9 |
| E | 575 | 9 | 0 | 6 |
| F | 2925 | 103 | 31 | 0 |
| G | 2862 | 51 | 58 | 22 |
| H | 3368 | 62 | 62 | 30 |
| I | 4538 | 154 | 99 | 30 |
| J | 1570 | 13 | 26 | 0 |
| | 21664 | 727 | 459 | 110 |

* The author is indebted to the Limoneira Company through J. D. Culbertson, for the use of these records.

This record shows that in two years the total number of newly infected trees decreased from 3.3 to 0.5 per cent and this decrease was apparently due to the adoption of preventive measures based on a knowledge of the real nature of the disease, gained from the experimental results described in previous sections of this paper.

The following data on the use of Bordeaux were also taken from the records kept by the Limoneira Company. In one orchard all trees with the exception of 8 rows of about 35 trees each, were sprayed with Bordeaux mixture two years in succession, from 1910 to 1911, and following this the surface of the ground and lower branches of the trees were sprayed each fall during 1912 and 1913. The records show the number of new developments of gummosis in 1914. Each set of 8 rows contained approximately 280 trees.

| Number of trees | Trees with lesions for first time | | Trees newly gumming at old lesions | | Total |
|---|---|---|---|---|---|
| | Number | Per cent | Number | Per cent | Per cent |
| Unsprayed 280 | 10 | 2.8 | 49 | 17.5 | 20.3 |
| Sprayed 280 | 3 | .9 | 24 | 8.1 | 9.0 |

It is seen that the unsprayed trees showed 2.8 per cent of newly infected trees, or somewhat the same as the average for 21664 trees in the same locality in 1912 before any preventive treatments were started (table 1). The sprayed trees, however, showed only 0.9 per cent newly infected, or about one-third as many. The continued development of the disease on old lesions was 17.5 per cent on unsprayed trees as against 8.1 per cent on sprayed trees.

An effective means of prevention for new plantings, and one especially desirable on heavy soils, is to use trees budded high, 1 to 2 feet or more, on resistant stocks, such as the sour-orange. The desirability of this stock because of its resistance, not only to Pythiacystis gummosis but also to psorosis and other gum diseases, has become so well recognized that a greater part of the new plantings in California are of trees having this stock.

*Treatment.*—Even when careful attention is given to prevention, a few cases of Pythiacystis gummosis will often occur from time to time, especially with trees on susceptible stocks planted in heavy soils. The following method of treatment has been adopted as the result of much experimental work in which the coöperation of citrus growers has been of great assistance.[25] The extent to which the bark is killed

[25] Fawcett, H. S., Calif. State Comm. of Hort. Monthly Bull. 2, pp. 601–617, 1913, and Prizer, J. A., Calif. State Comm. of Hort., Month. Bull. 4, pp. 7–19, 1915.

through to the wood is first ascertained by scraping slightly. Then the brownish killed bark (invaded zone) is dissected out with a heavy knife, cutting through to the wood about ½ inch beyond the invaded zone on the sides and 1 to 2 inches beyond at the top and bottom in a manner similar to that shown in figure 4*b*. The cuts on the two sides are ususally brought together above and below, making an acute angle. No attempt is made to cut beyond the outer gummous zone, since it has been shown that this zone does not contain the invading parasite. The live bark over this zone of gummous influence, not yet invaded by *Pythiacystis citrophthora,* will usually recover rapidly as

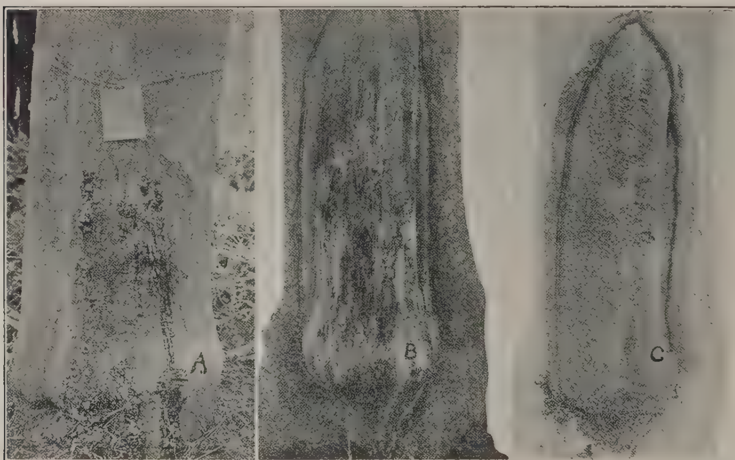


Fig. 4.—Method of cutting away diseased bark in treatment of a severe case of Pythiacystis gummosis.

(*a*) Result of inoculation with a bit of diseased bark on November 16, 1912. Photographed September 3, 1913. Invaded area 3×8.5 inches.

(*b*) Bark cut away September 3, 1913. Ready for painting with Bordeaux paste.

(*c*) Same tree on March 17, 1916, (3½ years later) showing growth at edges of wound and asphalt paint on exposed wood.

soon as the invaded portion has been removed and the further progress of the fungus has been stopped. These cut-out places and the entire trunk are then painted with Bordeaux paste (1 lb. copper sulphate and 2 lbs. rock lime to 1½ gallons of water) or some other suitable fungicide (see formulae under "Psorosis"). The fungicides other than Bordeaux paste most generally used in California are coal tar products from which the lighter oils have been distilled. Arrow Carbolineum and Creolineum XXX are trade names of some of those in common use.

The elimination of the tissue invaded by the causative organism is the most important feature of the treatment, the purpose of the fungicide being to prevent reinfection, or to kill the organism in small bits of tissue left behind.

After treatment the gum usually continues to exude for some time at the edges of the cut-out areas. This is left undisturbed except to examine the edges of the cuts to ascertain whether any bark is being


Fig. 5.—(*a*) Young lemon tree into which a sour-orange seedling ¼ inch in diameter had been inarched over a gummosis lesion about 2½ years before. The inarched seeding had increased to ¾ inch in diameter and had caused a ridge of growth above as shown alongside the white chalk mark.

(*b*) Old lemon tree showing gummosis lesion bridged by inarching sprouts from the base. About 5 years after inarching.

killed by further invasion of the fungus. The gum appears to act as a protective covering under which callous tissue is readily formed along the edges of the cuts. After these cut edges begin to heal, the exposed wood is painted with asphalt paint or other good covering (fig. 4*c*).

In cases where a large part of bark on the trunk has been killed by the rapid invasion of *Pythiacystis citrophthora*, so that the trunk

is girdled or nearly so, bridge grafting[26] and inarching[27, 28, 29], may often be resorted to in order to save the tree (fig. 5).

The advisability of this practice, in any particular instance, will depend upon the age and condition of the tree and other factors. A modification of the usual method of bridge grafting has been successful with citrus. Instead of a shoot or branch being grafted into the bark both above and below the injured portion, a sprout at or below the lower edge of the wound is allowed to grow. When of sufficient size the top part is cut off, bent over, and grafted into the bark above the diseased area (fig. 5*b*).

Another similar method of saving or aiding an injured tree is inarching, in which one or more small seedling trees are planted close to the trunk and the top grafted into the bark above the injury. Where quick relief is necessary and suitable sprouts cannot be stimulated, this method has proved beneficial (fig. 5*a*).

*Experiments in Treatment.*—At Santa Paula, through J. D. Culbertson of the Limoneira Company, and at Chula Vista, through J. A. Prizer of the San Diego Fruit Company, experiments planned in consultation with the author were carried out.

Previous to these experiments a large number of methods of treatment were tested, especially the method of slitting the bark and applying neat's foot oil, all of which gave unsatisfactory results except with trees treated when the lesions were very small. As soon as the investigation began to indicate that the disease was due to some infection the application of Bordeaux paste was used, first in connection with slitting (fig. 6) and later in connection with cutting away of the killed tissue of the lesion (fig. 4*b*).

Since a detailed report of these experiments at Chula Vista has been published by Prizer,[30] only a brief summary of the results will be included here.

In one orchard alternate rows were left without the Bordeaux as checks, but received the same treatment as to cutting away and slitting. The lesions were then divided into three classes called slight, medium and bad. The results of the first year's treatment (1912) before the

[26] Paddock, E. H., Bridge grafting on Citrus. Month. Bull. Calif. State Comm. Hort., vol. 81, pp. 72–73, 1919.

[27] Rundle, H. E., Inarching Citrus Trees. Calif. Cultivator, vol. 44, pp. 540–541, 1916.

[28] Hume, H. H., Citrus fruits and their culture, ed. 4, 196 pp., New York, 1911.

[29] Fawcett, H. S., Experiments in Bridge Grafting and Inarching in Connection with Gummosis of Citrus. Calif. Citrograph, vol. 8, pp. 68 and 95, 1923.

[30] Prizer, J. A., Calif. State. Comm. of Hort., Month. Bull., vol. 4, pp. 7–19, 1915.

method of cutting out was well perfected (it not yet being known how far cutting away was necessary) were as follows:

| Check (Bordeaux not used) | Cured | Still gumming | Trees dead |
|---|---|---|---|
| | Per cent | Per cent | Per cent |
| Slight | 81.2 | 18.7 | 0 |
| Medium | 50.0 | 50.0 | 0 |
| Bad | 7.1 | 21.2 | 71.5 |
| *Bordeaux used* | | | |
| Slight | 82.3 | 17.6 | 0 |
| Medium | 62.5 | 37.0 | 0 |
| Bad | 23.0 | 66.0 | 11.0 |

It is to be noted that the difference in cured lesions in favor of the application of Bordeaux after cutting is not large in the slight and medium classes. In the bad class, however, the proportion of cures is 23 per cent for the Bordeaux against 7.1 per cent for the check, while the dead trees in this class are only 11 per cent for the Bordeaux against 71.5 per cent for the check.

The results for a period of three years, 1912–1914 inclusive as obtained in treating 209 new lesions on trees which had not been infected before, are of interest.

| Stage of disease | Trees cured | | Trees still gumming | | Trees dead | |
|---|---|---|---|---|---|---|
| | Number | Per cent | Number | Per cent | Number | Per cent |
| Slight | 115 | 95 | 5 | 4.1 | 1 | .9 |
| Medium | 37 | 80.4 | 7 | 15.2 | 2 | 4.3 |
| Bad | 35 | 83.3 | 2 | 4.7 | 5 | 11.9 |

The results show that although a large percentage of the trees in the bad classes may be cured, a still larger percentage of those in the slight class yield to treatment. It is important, therefore, to inspect all trees sufficiently often to detect as far as possible all cases when slight, not only because of the decrease in loss of trees themselves, but to prevent severe injury from loss of bark. Prizer considers it necessary in the case of heavy soils near the coast to make not less than three separate tree-to-tree inspections a year, and possibly four on the worst orchards.

In the Limoneira Company orchards at Santa Paula, similar methods of treatment were carried out with satisfactory results as far as Pythiacystis gummosis was concerned. The Botrytis gummosis was

more prevalent in these orchards than in the Chula Vista orchard and because of the different character of the disease a method of scraping off the outer cortical layers, as well as cutting out entirely to the wood was worked out. It is described more fully under that disease.

Later the Limoneira Company desired to displace the Bordeaux, if possible by some other fungicide, partly because the presence of Bordeaux when followed by fumigation with hydrocyanic acid gas was thought, under the climatic conditions at Santa Paula, to emphasize the injury to the foliage. The writer was asked to suggest some substitutes for trial, and the following materials were tried out on 6-year-old trees by the Limoneira Company: (1) Carbolic acid (5%) 1 part, and liquid whale-oil soap, 1 part, on 2 trees; (2) Avenarius carbolineum, 1 part, emulsified with 3 parts of liquid whale-oil soap, on 2 trees; (3) corrosive sublimate, 1 gram in 1000 c.c. of denatured alcohol, on 1 tree; (4) Rex limesulfur solution, 1 part to 1 part of a paste of lime, to give it body, on 2 trees; (5) Bordeaux paste (1-2-1½) on 1 tree; (6) No application, as control, 4 trees.

These trees were examined from time to time for two years and no marked difference in the recovery of any of them that could be attributed to the application of one substance over another, could be made out. Avenarius carbolineum full strength and corrosive sublimate, 1 part to 1000 parts of denatured alcohol, and lime-sulfur solution diluted with equal parts of water, were used in the same way at Whittier in September, 1915, with results similar to those at Santa Paula.

Since all the trees recovered, even the checks, it is indicated that the proper dissection of the diseased bark is probably more important than the fungicide applied to the wound. The writer[31] had used Avenarius carbolineum emulsified with equal parts of soap and water in Florida for certain diseases of orange trees. In 1916 C. C. Miller, who had used Avenarius carbolineum at full strength without injury, on deciduous trees, began using this substance as a substitute for Bordeaux. Miller's[32] first report of this treatment is likely to be misleading because he was not then familiar with the difference between the different types of citrus gummosis and because he conducted no extensive, well checked, comparative experiments comparing carbolineum and other substances. It is now indicated that any good fungicide that is not injurious to the bark is efficient for use in the treatment of this disease.

---

[31] Fawcett, H. S., Florida Agr. Exp. Sta. Bull. 106, 1911.

[32] Miller, C. C., Month. Bull. Calif. State Comm. of Hort., vol. 7, pp. 488–493, 1918.

An example of what can be done in controlling Pythiacystis gummosis when it is treated promptly and with care, is furnished by a five-acre lemon orchard at Whittier on clay loam soil, previously re-

Fig. 6.—Showing a method formerly used in treating brown-rot gummosis by cutting vertical slits in the bark, one on each side of the diseased lesion and several down through the invaded area. This treatment appeared to be of some value for mild cases, but was useless for more severe outbreaks.

ferred to, where conditions facilitating infection obtained. About 20 per cent of the 6-year-old trees became infected after a period of heavy rains following the application of green, freshly cut barley about the trunks in March, 1914.

The lesions noticed in May varied in size from those just started to lesions extending one-half to two-thirds around the circumference of the bark on the trunk. On May 25, 1914, the trees were treated by dissecting out all the brown killed bark (invaded zone) and cutting about ½ inch beyond this invaded zone on the sides and 1 to 2 inches beyond at the top and bottom, as is shown in fig. 4*b*. The cuts on the two sides were usually brought together above and below, making an acute angle.

No attempt was made to cut beyond the outer gummosis zone of gummous influence, so that in most cases on larger lesions this zone probably extended into the remaining bark a considerable distance beyond the cuts. As has been pointed out in the description of the disease and elsewhere, the margin of the zone actually invaded by the causal fungus usually lags far behind the zone in which gum formation occurs. These cut-out places and the entire trunks were painted with Bordeaux paste (1 lb. copper sulfate and 2 lbs. rock lime to 1½ gallons water). In order to prevent further infection the soil was pulled back from the trunk as far as the top of the first main roots.

After treatment the gum continued to exude in considerable quantities at the edges of the cut-out areas. This gum was left undisturbed except for examining the edges of the cuts to ascertain whether the bark was being killed further. The gum appeared to act as a protective covering under which callous tissue was soon seen to be forming rapidly along the edges of the cuts.

On June 22, 1914, about one month after treatment, an inspection showed only 5 trees with new areas of killed bark, all of which areas were on trees previously treated. On August 3, 7 additional areas of killed bark were found, and on September 15, 8 additional areas, all except 2 of which were on trees previously treated.

On March 29, 1915, a rapid healing was noted at all the cuts and no effect on the foliage could be detected. Three new lesions, all originating below the surface of the soil, were found.

On July 30, 1915, 3 trees which had lost bark from areas extending over two-thirds to three-fourths their trunk circumferences, were showing a slight yellowing of the foliage, but only on branches directly above the dissected areas. By March 6, 1916, however, only one tree showed any appreciable effect of the removal of bark and this was one from which about 120 square inches had been removed. The trunks of all the trees had been painted again with Bordeaux paste in the fall of 1915, and no new cases were found during the spring and summer of 1916.

The rapidity of healing of cut-out places of various sizes is indicated by table 2. These figures were obtained by measuring the areas in two directions and estimating the number of square inches in each. While the figures are only approximate, they give a rough idea, at least, of the rate at which the different sized areas on lemon trees of this age may be expected to close up with new bark tissue.

TABLE 2

| Number of areas | Size of original areas, May 1914 | Average size of areas, June 1916 | Average size of areas, April 1921 |
|---|---|---|---|
| | sq. in. | sq. in. | sq. in. |
| 5 | .5 | 0.0 | 0.0 |
| 3 | 1.0 | .08 | 0.0 |
| 8 | 2.0 | .97 | 0.0 |
| 4 | 3.0 | 1.2 | 0.0 |
| 10 | 4.0 | 2.7 | 0.6 |
| 2 | 5.0 | 3.5 | 0.5 |
| 5 | 6.0 | 3.7 | 0.0 |
| 4 | 7.0 | 2.5 | 0.9 |
| 7 | 8.0 | 4.0 | 0.6 |
| 5 | 10.0 | 4.2 | 1.0 |
| 2 | 11.0 | 8.0 | 2.0 |
| 5 | 12.0 | 9.8 | 3.2 |
| 3 | 16.0 | 11.3 | 5.0 |
| 5 | 22.0 | 17.0 | 5.6 |
| 4 | 35.0 | 27.0 | 7.5 |
| 3 | 40.0 | 22.0 | 15.0 |
| 7 | 50.0 | 42.5 | 25.0 |
| 4 | 75.5 | 55.0 | 23.7 |
| 5 | 105.6 | 69.0 | 39.6 |
| 1 | 130.0 | 80.0 | 60.0 |

It will be noted that all wounds less than 3 square inches in size at time of treatment were closed, or insignificant, at the end of 2 years. Nearly all wounds less than 10 square inches in size at time of treatment were closed in 7 years. Areas larger than 10 square inches at time of treatment were reduced to about one-half to two-thirds of their original size in 2 years and about one-third to one-fourth their original size in 7 years.

## TREATMENTS FOR GUMMOSIS TO BE AVOIDED, OR USED WITH CARE

A treatment for wounded tree trunks, mention of which is found in very early literature, is the use of fresh cow dung applied to the surface of wounded tissue. Whatever value this practice may have for mechanical wounds, when parasitic organisms happily do not get

started in such a medium, it is certainly extremely dangerous when applied to tree trunk affected with either Pythiacystis or Botrytis gummosis, for the reason that ideal conditions for growth of the fungus parasites would seem to be furnished by the presence of the fresh, moist cow dung.

An example of the results of such practice will be briefly mentioned here.

In February, 1913, on the advice of a foreign expert in citrus culture, a grower treated a large number of trees that had previously had gummosis, by coating their entire trunks with cow dung, then wrapping them first with newspapers and over this, burlap. A bunch of dry weeds and grass was then placed in the forks of the branches. Fifteen pounds of sulfur was added to every 50 gallons of the dung. During the latter part of May it was discovered that a large amount of softening, dying and decaying of new bark was going on under these wraps. Gum pockets were forming on large limbs above the wrappings under the bunches of grass in the forks. All wraps were then removed as fast as possible, the dung scraped off, the dead, soft, decaying patches of bark cut away and the entire trunk painted with Bordeaux paste. It is not possible to say definitely what would have happened to these trees if the wraps had remained, but many of them would probably have been injured beyond recovery by the rapid increase in the decay of bark under the burlap.

Records had been kept of 1023 trees so treated. Of these 293 had previously had their trunks painted with Bordeaux paste in connection with gum disease treatment. The remaining 730 had not been painted with Bordeaux previous to wrapping. It was interesting, therefore, on removal of the wraps, to compare the condition of the trunks bordeauxed before wrapping with those not so treated. The following data were obtained:

| Trees not Bordeauxed before wrapping | Gummosis active on removal of wraps<br>Number | Per cent |
|---|---|---|
| 730 | 486 | 66.6 |
| Trees Bordeauxed before wrapping | | |
| 293 | 31 | 10.6 |

These results seem to show that the presence of the Bordeaux under the dung at time of application prevented a greater part of the damage in the case of the trees so treated.

Another treatment which frequently results in injury to the trees is the use of neat's foot oil. Considerable evidence has been collected to the effect that this substance has often killed considerable bark or furnished a condition which was favorable to the growth of the parasites. Experiments in the laboratory showed that *Pythiacystis citrophthora* grew as well on the surface of bark previously treated with neat's foot oil, as on that which had not been treated, and *Botrytis cinerea* grew much better on bark to which neat's foot oil had been applied.

Light, penetrating oils, such as kerosene, should be used with much caution on citrus bark. A number of cases have been observed where kerosene applied at the base of the tree trunk caused the death of the bark at and below the surface of the soil.

## MAL DI GOMMA, OR FOOTROT

Mal di gomma, due to *Phytophthora terrestria* Sherbakoff, is a gum disease with close relationships to Pythiacystis gummosis. Certain phases of the Pythiacystis gummosis occurring on, or near, the main roots of sweet-orange trees, are quite similar to those of mal di gomma, or foot rot. For this reason, certain foot rot-like forms, due to *Pythiacystis citrophthora* in California, have previously been referred to as mal di gomma.[33, 34] Since the term mal di gomma was used first in Florida to designate a common Florida gum disease, which is now known to be induced by *Phytophthora terrestria,* it is proposed to restrict its use (in this country at least) to the disease due to this fungus.

### SYMPTOMS

This type of gum disease affects, for the most part, the bark on the lowest portion of the trunk and the upper portion of the highest main roots, mostly below the surface of the soil. Gum usually forms on the trunk of the tree above the soil. The inner bark and finally the wood underneath frequently develop a fetid odor.* The bark

[33] Smith, R. E., and Butler, O., Gum Disease of Citrus Trees in California. Calif. Agr. Exp. Sta. Bull. 200, pp. 235–272, 1908.

[34] Fawcett, H. S., The known distribution of *Pythiacystis citrophthora,* and its probable relation to mal di gomma. Phytopathology, vol. 5, pp. 66–67, 1915.

* This rotting of the wood, as well as the bark, and the accompanying fetid odor are believed to be due mainly to secondary organisms setting up fermentation and decay below the surface of the soil after killing of the bark by the primary organism. While gum may be formed below as well as above the surface of the soil, it is dissolved readily by moisture and is usually less conspicuous below the soil surface. This disease, under California conditions, cannot be distinguished from certain phases of brown rot gummosis except by means of culture tests for isolating the causal organisms.

dies and breaks away in patches, leaving bare, dead areas, which spread in all directions, but mostly downward, on the main crown roots and laterally around the trunk (fig. 8). Trees thus affected bear heavy crops of fruit temporarily and the leaves become yellow.

## HISTORY

This gum disease was first known as foot rot and attracted attention in Florida about the same time that Pythiacystis gummosis was noticed in California. Curtiss,[35] in 1888, reported that it appeared in 1876, although few people, he says, remember having observed it before 1880. That the disease was not important in Florida before that time is indicated by the fact that Bishop,[36] writing on citrus culture in Florida in 1875, discusses a number of other diseases but does not mention this one.

In a book published in 1881, Moore,[37] who made extensive observations on citrus culture in Florida, speaks of this disease under "foot rot" as having appeared in "late years" in Florida. In 1896 Swingle and Webber[38] stated that the disease was widely distributed in Florida and seemed to be gradually spreading.

## INVESTIGATIONS

Only once has the causal fungus been isolated in California. This was from an orange tree at Lindsay in 1912. It was considered by the writer at that time to be only a peculiar strain of the brown rot fungus, *Pythiacystis citrophthora,* but was later identified by Sherbakoff as the same species which he had previously described.[39] This species, or a closely allied one, appears to be widely distributed, occurring in a number of countries. It was found on citrus[40, 41] in Florida, Cuba and Argentine, on coconuts, tobacco and pineapples in Jamaica,[42] on tomatoes in Florida[38] and castor oil plants and Vinca in India.[43]

---

[35] Curtiss, Sore Shin or Gum Disease. Fla. Agr. Exp. Sta. Bull. 2, 1888.

[36] Bishop, P. P., Proc. Am. Pomo. Soc., p. 48, 1875.

[37] Moore, T. W., Treaties and handbook of orange culture, New York, 1881.

[38] Swingle, W. T., and Webber, H. J., The principal diseases of citrus fruits in Florida. U. S. D. A., Div. of Veg. Phys. and Path. Bull. 8, 1896.

[39] Sherbakoff, C. D., Buckeye rot of tomato fruit. Phytopathology, vol. 7, pp. 119–129, 1917.

[40] Fawcett, H. S., Pythiacystis and Phytophthora. Phytopathology, vol. 10, pp. 397–399, 1920.

[41] Stevens, H. E., Florida citrus diseases. Fla. Agr. Exp. Sta. Bull. 150, 110 pp., 1918.

[42] Ashby, S. F., Leaf-stalk rot caused by *Phytophthora parasitica.* In west Indian Bull. vol. 18, pp. 70–73, 1920.

[43] Dastur, J. F., *Phytophthora parasitica* new species; a new disease of the castor oil plant. Mem. Dept. Agr. India, Bot. Ser., vol. 5, pp. 177–231, 1913; *idem.*, Phytophthora on *Vinca rosea.* Mem. Dept. Agr. India, Bot. Ser., vol. 8, pp. 233–242, 1916.

Fig. 7.—Mal di gomma or foot rot. (*a*) On 40 year old seedling orange trees. White lines indicate boundaries of killed bark. (*b*) Earth dug away and effected bark and roots being removed before applying Bordeaux paste.

Many comparative inoculations, with *Pythiacystis citrophthora*, the cause of brown rot gummosis, and *Phytophthora terrestria*, the cause of mal di gomma, were made under various conditions and the same type of lesion was produced by both fungi. There was an indication in some of the experiments that sweet-orange bark was more susceptible than lemon to *Phytophthora terrestria* while the reverse was generally true of the fungus of brown-rot gummosis. According to Hume[44] in Florida the sweet-orange is more susceptible to mal di gomma than the common lemon, and sour-orange is very resistant.

The relation of temperature to growth is somewhat different for the two fungi.[45] While the optimum temperature for sustained growth over a period of several days in the laboratory for *Pythiacystis citrophthora* is about 77°F. (25°C.), that for *Phytophthora terrestria* is about 86°F. (30°C.). It is of interest in this connection that the rainy season in California occurs during winter and spring, coincident with moderate temperatures, while the moist season in Florida occurs during the summer, coincident with much higher temperature.

## CONTROL

The means of prevention and treatment of mal di gomma, are essentially the same as those for brown-rot gummosis, a certain form of which it so closely resembles that only laboratory examination can distinguish the two diseases. Care regarding excessive moisture in contact with the bark of the crown roots and the base of the trunk, care in keeping the soil away from the base of the tree and in avoiding injuries, the use of sour-orange stocks for new plantings, the use of fungicidal washes on the bark, are all useful in prevention. For detailed suggestions regarding prevention and treatment, see under brown-rot gummosis.

---

[44] Hume, H. H., Some Citrus troubles. Fla. Agr. Exp. Sta. Bull. 53, pp. 145–173, 1900.

[45] Fawcett, H. S., The temperature relations of growth in certain parasitic fungi. Univ. Calif. Publ. Agr. Sci., vol. 4, pp. 183–232, 1921.

## BOTRYTIS GUMMOSIS

### SYMPTOMS AND OCCURRENCE

Botrytis gummosis[46] differs from brown-rot (Pythiacystis) gummosis, in that it causes softening of the invaded bark in the early stages and shows a grey color on the surface in damp, cool weather, caused by the conidiophores and spores of the fungus (fig. 9). In the later stages the outer layer of bark is killed and becomes dry and hard much in advance of the inner layer, while there is a greater tendency than in brown-rot gummosis for the tree to renew the bark underneath the dead, hard layer, and there is usually also a less copious flow of gum. Unlike brown-rot gummosis, Botrytis gummosis is confined in California almost exclusively to lemon trees growing in the coastal regions, and usually occurs on trees that are more than 10 years of age. This disease should not be confused with "shell bark," a desquamated bark condition in which the outer bark of lemon trees dies, cracks and breaks away in longitudinal strips, a condition which is somewhat similar to that frequently brought about in the later stages of Botrytis gummosis. These two diseases are often associated on the same trees. The conditions favorable to the one are also apt to encourage the other. Neither disease should be confused with psorosis (scaly bark) of sweet-orange trees.

Unlike *Pythiacystis citrophthora,* this fungus is not able to gain entrance except through some wound or defect in the bark, and is not able to progress so rapidly in killing the bark through to the wood. A large area is involved, in which only certain outer layers of bark tissue are killed, leaving the cambium alive and capable of renewal. This gummosis produces an outer gummous zone beyond the invaded area, but this is usually less extensive and less rapidly formed than with Pythiacystis gummosis. Other conditions being equal, there is usually somewhat less gum formation in Botrytis gummosis than in Pythiacystis gummosis.

The writer's attention was first called to this type of gummosis early in February, 1912. After a period of moist, cool weather, patches of bark 6 to 12 inches long and half as wide presented the gray furry appearance characteristic of the fruiting bodies of *Botrytis cinerea* (fig. 8). In a later survey of the citrus districts of California, *Botrytis cinerea* was always found associated with this type of gummosis and was isolated from a large number of diseased trees.

---

[46] Fawcett, H. S., "Two fungi as causal agents in gummosis of lemon trees in California," *in* Month. Bull. Calif. Comm. Hort., vol. 2, pp. 601–617, 1913, and Phytopathology, vol. 4, p. 54, 1914.

## INVESTIGATIONS AS TO NATURE AND CAUSE

The investigations establishing the relation of the fungus *Botrytis cinerea* to this disease, were conducted in much the same way as those in connection with brown-rot gummosis.

(1) Inoculation with diseased tissue showed that the disease could be transmitted to sound bark of healthy trees.

(2) Cultures from the diseased lesions showed the presence of a fungus, *Botrytis cinerea,* previously known as the Botrytis rot fungus of the packing houses.

(3) By inoculation experiments with pure cultures of this fungus the characteristic symptoms were induced on healthy trees (fig. 9).

(4) Inoculation with Botrytis fungus isolated from lemon fruits also produced the same results.

(5) The Botrytis fungus was again isolated from the artificially induced lesions and was found capable of inducing rot in lemon fruits irrespective of whether it had been found originally in diseased bark or in rotting fruit. Some of the details of this work are being published in the Journal of Agricultural Research.

The fungus was isolated from the softened invaded area of a large number of these lesions. Attempts to isolate the fungus from the outer gummous zone, however, failed, just as they did in Pythiacystis gummosis. Only rarely was Botrytis isolated from the area where the outer bark was dead and hard. Cultures showed that following Botrytis inoculation this outer dead cortical layer is rapidly occupied under such conditions as prevail at Santa Paula by species of Alternaria, Cladosporium, Penicillium, Colletotrichum, Fusarium, and other fungi and bacteria.

## FACTORS FAVORING THE DISEASE

Many contributing conditions tend to favor the occurrence and the severity of this disease. Some of these are similar to those which favor Pythiacystis gummosis, as discussed under that disease.

Injuries of various kinds to the bark, not only near the soil, but anywhere on the trunk or large branches, may lead the way to infection and development of Botrytis gummosis when the conditions of moisture and temperature are also favorable. This disease is frequently severe on living tissue of trees that have been injured by frost. The fungus may first become established in such trees in a small portion of dead or dying tissue and then advance rapidly into tissue which appears to be sound.

Fig. 8.—Grey masses of spores of *Botrytis cinerea* on the surface of bark of a Botrytis gummosis lesion.

A desquamated condition of bark, fairly common on old lemon trees in the California coastal regions, is also frequently accompanied by Botrytis gummosis. It furnishes dead outer bark tissue from which the fungus may advance. The desquamated condition is similar in appearance to that which usually follows inoculation with *Botrytis cinerea* on sound tree trunks and with which it is often confused. It is thought, however, to be due to other causes. Recent experiments have shown that a species of Phomopsis, to be described as *P. californica* is probably a factor in causing "shell bark."

The previous use of neat's foot oil in the treatment of gummosis encouraged the growth of the Botrytis fungus. The trunks of lemon trees previously treated at Santa Paula by scoring the bark and painting with neat's foot oil were observed in February and March of 1912 to be fairly well covered with a gray coating consisting of the sporophores and spores of Botrytis. The bark on these trees was found to be in various stages of soft decay with the exudation of large masses of gum. Experiments also showed that this fungus develops better on lemon bark treated with neat's foot oil either before of after infection by the organism than on bark free from this oil. More recently the application of neat's foot oil to citrus trees has been largely given up, and the more severe stages of this disease, such as were previously seen, have not been observed lately.

## METHODS OF CONTROL

The control methods used for Botrytis gummosis as in the case of Pythiacystis gummosis are of two kinds, prevention and treatment; both of which are similar in principle to those discussed in connection with the former disease. A few modifications, however, based on the differences in the latter disease should be pointed out.

*Prevention.*—Since *Botrytis cinerea* appears to be dependent upon abrasions or other injuries for its entrance into lemon bark, especial care is necessary, particularly in moist weather, to avoid injuries in cultivation, picking and other orchard operations. The danger from such injuries may be lessened by painting the tree trunks with Bordeaux paste or other fungicides or spraying them thoroughly with Bordeaux mixture. The precaution previously mentioned of pulling away soil that is too high against the trunk and of keeping water as much as possible away from the trunk, are also applicable in the case of Botrytis gummosis.

*Treatment.*—The principle governing the treatment of this type of gum disease is the same as that for Pythiacystis gummosis, namely, the elimination of the invaded tissue and the prevention of further

progress of the disease. As the result of many different experiments in which growers took a prominent part, a method consisting largely of scraping off the outermost layers of bark was found which proved to be best adapted for treatment of this disease (fig. 10). The portion where the bark is totally killed is cut away, but beyond this where usually only the outer layers of bark are dead, these outer layers only are scraped off, leaving intact the live inner layer next to the cambium.

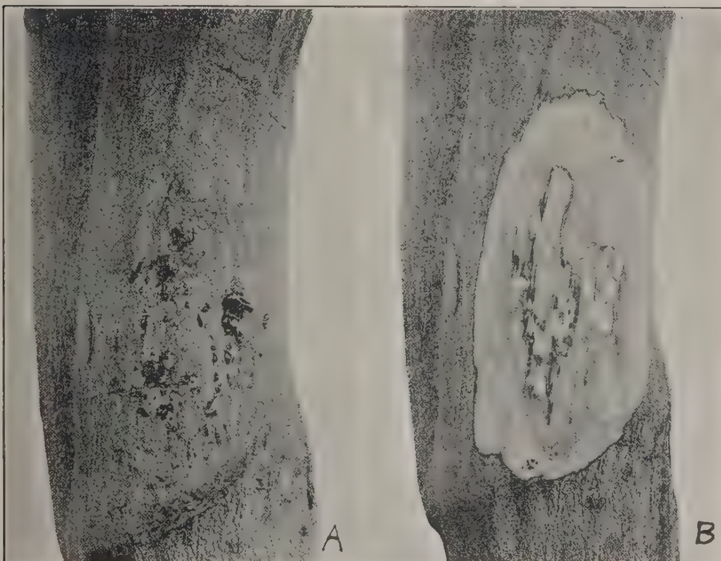


Fig. 9.—(*a*) Gum exudation on a lemon trunk as the result of inoculation with the Botrytis fungus.

(*b*) Bark over and around the diseased lesion scraped, to show the extent of the dead soft bark.

To prevent further invasion of the outer bark it is usually found necessary to scrape the sound bark several inches beyond the margin of the affected region. A sharp curved tool, described under "psorosis," which can be easily controlled in scraping, is in general use for this purpose (fig. 13). This modification of the method used for Pythiacystis gummosis is advisable because of the different nature of the disease, in order to preserve as much as possible of the inner live bark. Where both types of gummosis are present on the same trees, as is frequently the case, this method is still applicable to the combined lesions produced. The cut or scraped portions are then painted

with a fungicide (fig. 10*b*). Bordeaux paste, and some of the coal tar products, such as Avenarius Carbolineum, Arrow Carbolineum and Creolineum XXX, which contain only the heavier oils, have given good results.

The following is a typical example of the many experiments in treatment of this disease:

On October 8, 1912, at Santa Paula, a lesion on the trunk of an 18-year-old lemon tree was treated by cutting away the bark entirely in a few small places where it was killed to the wood, but scraping away only the dead outer layers and leaving the cambium still attached (fig. 10*a*). The scraping was done with a sharp curved instrument made on the principle of a box scraper, and the scraped portion was then painted with Bordeaux paste (fig. 10*b*).

On May 10, 1913, new bark was building up over the scraped portion, but the disease had spread slightly on the margins where scraping had not been continued out far enough.

On May 17, 1914, new bark was seen to have formed over the entire scraped portion and the disease appeared to be entirely stopped.

## SCLEROTINIA GUMMING DUE TO SCLEROTINIA LIBERTIANA

This disease, usually of minor importance, occasionally has been found associated with rapid dying of bark on the roots and trunks of citrus trees growing in damp, cool locations especially after periods of severe frost. The bark is at first soft just as in the case of attack by *Botrytis cinerea.* Though this fungus usually advances more rapidly than Botrytis, it is soon checked, and callus begins to form as soon as gum accumulates. Later, as the bark dries, it is left in shreds (fig. 11) and large black sclerotia are found within and under this bark. Its effect on citrus twigs has been described by C. O. Smith,[47] who refers to the gumming usually accompanying its attack. It appears to infect the young growth, usually at the blossoming period, and frequently extends back into larger branches.

When the fungus is found on the trunk or roots, observations have indicated that previous injury of the bark was usually necessary for its entrance. It has frequently been found on young trees following frost injuries, apparently advancing from frost injured tissue into tissue not killed by frost. It has been observed on a lemon tree 20 years old where all the roots had been infected, probably from injuries made in digging about them and placing vetch straw near the crown

[47] Smith, C. O., Cottony rot of lemons in California. Calif. Agr. Exp. Sta. Bull. 265, pp. 237–258, 1916.

in damp cool weather. An old seedling orange tree also was observed with the bark on one side of the trunk killed by the fungus, which had apparently gained entrance through a small sunburned area and had advanced into the live bark for some distance.

Fig. 10.—Treatment of Botrytis gummosis.
(*a*) Lesion being scraped.
(*b*) Painting scraped area with Bordeaux paste.

This fungus has also been shown by inoculation experiments to be capable of advancing rapidly into lemon bark, inducing copious gum formation for a short time only. Observation shows that the halting of the invasion of the fungus is usually coincident with the exudation of considerable quantities of gum. The prevention and treatment of this disease is the same as that for Botrytis gummosis. (See directions under Botrytis gummosis, page 404.)

## PSOROSIS (SCALY BARK) OF ORANGE TREES

Although psorosis is generally classed as a gum disease, gum exudes only at certain seasons, or during certain phases of development of the disease, and then the gum is usually not so conspicuous a feature as it is with brown-rot gummosis.

This disease was briefly described by W. T. Swingle and H. J. Webber in 1896 in Florida and given the name of psorosis.

It is now known in California as "scaly bark," but must not be confused with another disease known in Florida as scaly bark (nail-head rust). This last is distinct from psorosis and does not occur in California.

The slowness of the development of the disease, and its inconspicuous appearance and lack of effect upon the foliage in the earlier stages, frequently prevent it from being noticed until it is far advanced.

### SYMPTOMS

The most conspicuous feature of the scaly-bark disease is the appearance on the trunk or large limbs, of irregular scales of bark ¼ to 1 inch in diameter, standing out as if pushed off from the surface (fig. 12). It usually begins with a very small area in which only a thin outer layer of bark dies, hardens, and is raised from the surface, leaving a layer of bark underneath still alive. This first area slowly enlarges from year to year until finally it encircles the trunk or limb. Often a number of small areas begin at the same time and thus cover the surface more rapidly. Later the deeper layers of bark and even the wood may be affected. Gum may exude as the disease advances, but gum is not a necessary accompaniment of the disease and its presence and amount depend on growth conditions, season of the year, etc.

### INVESTIGATIONS AS TO CAUSE AND MANNER OF DEVELOPMENT

An investigation into the cause and manner of development and control of this disease, has been carried on for years. Many difficulties which were not encountered in the work with brown-rot gummosis have arisen in the investigation of the cause of psorosis. One of these has been the extreme slowness with which the disease develops in its incipient stages.

In certain cases it has been possible to transmit the disease to sound trees by inoculations with bits of tissue from diseased lesions, but many of the attempts have failed. In one successful case two years elapsed after the diseased tissue was placed in a wound in sound bark,

before any sign of the disease was noted. This suggests that an organism of some kind which is able to advance very slowly may be the immediate cause of the disease. Experiments planned to determine

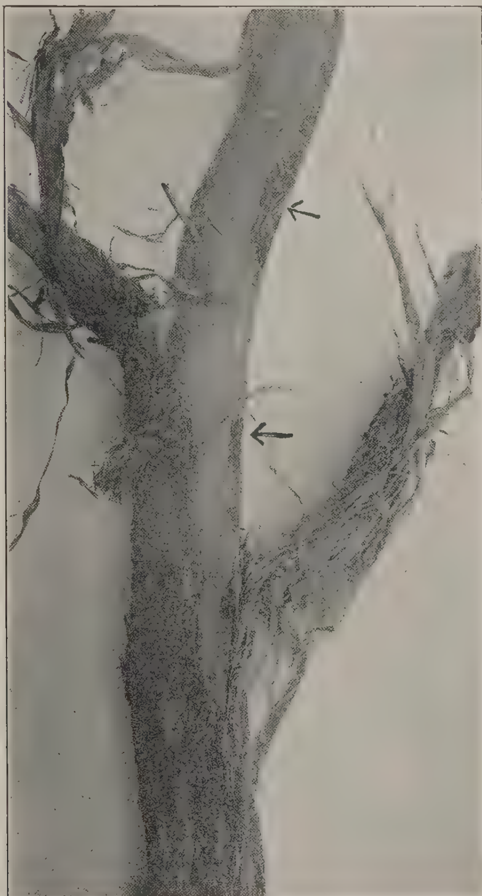

Fig 11.—Root of lemon tree showing shredded appearance of the bark and the black sclerotia as the result of the attack of *Sclerotinia libertiani* . Arrows point to sclerotia.

whether this hypothesis is correct have been under way for some time, but because of the slowness of development of Psorosis from the early stages there has not been time for proof of this conjecture to be established.

As examples of the slowness with which the disease often develops, the following cases may be mentioned. At the Experiment Station two incipient lesions not yet gumming, and each about 1 inch in diameter were outlined on a Valencia orange tree 12 years old. These lesions had progressed only 1/4 inch beyond the original mark in 2 1/2 years. A slightly larger area on another tree, which was 1 1/2 inches in diameter when first observed became only 4 inches in diameter in 3 1/2 years. These areas were so small and inconspicuous when outlined that they would not have been noted at all at that stage by the average grower.

After the lesions become larger, however, they develop somewhat more rapidly. The following example represents a rather rapidly developing lesion. An area on a trunk of a 12-year-old Valencia tree was 3×7 inches when marked. Six months later it was 8×12 inches; after 9 months, 10×15 inches; after 2 years, 12×16 inches (with much gumming), and after 3 1/2 years 14×17 inches. While this increase from 3×7 inches to 14×17 inches seems considerable in itself, it represents an average of only about 1 1/2 inches of advance per year in any one direction. The lesion was probably 3 to 4 years old when first measured. Scaly bark thus differs from any other gum diseases, whose whole course of development can be followed out in 1 or 2 years.

The visible advance of the disease depends greatly upon the season of the year. In the majority of cases it seems to be most active during the growing season and especially in summer and early fall, and to be quiescent during the winter and early spring. This great show of activity is due in part to the breaking away of scales of bark, probably brought about not only by drying of the outer bark that has previously died, but also by the increase in growth of the inner live bark beneath. Gum formation and exudation also take place at this season, giving further indication of activity. Most of the advance for the year, however, appears to be finished when the gum formation is at its maximum. The gum is the result and not the cause of the death of the outer bark. The gum probably tends to hinder more than to aid the advance of the disease at this time.

## EXPERIMENTS IN TREATMENT

Although the investigation as to the cause and manner of development of the disease received first attention, a number of experiments in control have also been carried on. Various methods of cutting, scraping and slitting the bark have been compared with no cutting or scraping. Comparisons have also been made of the application of a considerable number of substances as fungicides or coverings.

Without going into detail, it may be said that a method of scraping the outer bark to depths varying according to circumstances, to be described later, has been found more effective than any other method. Scraping has been found to be much more important than the use of any kind of fungicide or disinfectant. Slitting has proven of little or no value in these experiments. These experiments have also shown the advisability of scraping not only the area visibly affected, but also beyond the area to a distance of from 6 to 8 inches to head off the advance of the disease in bark not yet visibly affected. The spread of a lesion in its early stages appears to take place within the outermost layers of bark. This accounts for the beneficial results of light scraping beyond the visible edge of the lesions.

A large number of disinfectants and coverings were tested with and without scraping or other method of cutting the bark. In each case similar areas on the same or different trees were left without the application of the disinfectant for comparison. Almost without exception the diseased trees on which the bark was carefully scraped showed the best recovery. The disinfectant applied seemed to have little effect. Lesions of the same kind not scraped continued to develop in size at the same rate, whether painted or unpainted with the various disinfectants.

A coöperative experiment was also carefully conducted under commercial conditions by M. B. Rounds[48] of the Azusa Foothill Citrus Company. Methods of scraping and slitting the bark, combined with applications of Bordeaux paste, Creolineum XXX and emulsified cresol (liquor cresolis compositus U. S. P.), respectively, with check trees for comparison, were instituted according to the following plan: Most of the trees treated were in the first and second stages and were chosen with an attempt to get sets of like specimens for each combination of treatment.

| | Check | Bordeaux | Creolineum | Emulsified cresol |
|---|---|---|---|---|
| Check, not scraped | 4 trees | 5 trees | 5 trees | 5 trees |
| Scraped | 5 trees | 5 trees | 5 trees | 6 trees |
| Scraped and slit | 5 trees | 5 trees | 5 trees | 5 trees |
| Slit | 5 trees | 5 trees | 5 trees | 5 trees |

The scraping was done according to the method described below and the slitting by making long vertical slits with a heavy knife, through and on either side of the diseased lesions. The trees were

48 Rounds, M. B., California Cultivator, vol. 8, p. 222, 1922.

treated in October, 1921, and the following results are reported by Mr. Rounds for August, 1922.

| | | Disease still progressing Number of trees | Disease not progressing Number of trees |
|---|---|---|---|
| Not scraped or slit | Check | 3 | 1 |
| | Bordeaux | 4 | 1 |
| | Creolineum XXX | 5 | 0 |
| | *Emulsified cresol | 4 | 1 |
| | | 16 | 3 |
| Scraped | Check | 0 | 5 |
| | Bordeaux | 0 | 5 |
| | Creolineum XXX | 0 | 5 |
| | Emulsified cresol | 0 | 6 |
| | | 0 | 21 |
| Scraped and slit | Check | 0 | 5 |
| | Bordeaux | 0 | 5 |
| | Creolineum XXX | 2 | 3 |
| | Emulsified cresol | 0 | 5 |
| | | 2 | 18 |
| Slit only | Check | 3 | 2 |
| | Bordeaux | 3 | 2 |
| | Creolineum XXX | 4 | 1 |
| | Emulsified cresol | 3 | 2 |
| | | 13 | 7 |

* Liquor cresolis compositus U. S. P., full strength.

While it is too soon to draw definite conclusions from this experiment alone, because of the slowness of development of the disease, the results, taken together with experiments made at the Experiment Station and many other observations, indicate that the particular fungicide to be applied is of less importance than the manner of scraping or treating the bark. None of the trees scraped alone showed any advance of the disease, while 65 per cent of those slit alone, and approximately 80 per cent of those not scraped or slit, showed an an advance in the disease at the time here recorded.

## SUGGESTIONS FOR TREATMENT

The stage of the disease largely determines how each tree should be handled. Each tree affected presents an individual problem. Certain tentative suggestions, however, will be made here, it being understood that these apply to typical conditions and that they may need modification when applied to any particular case.

Fig. 12.—About the second stage of psorosis (scaly bark) on orange trees, showing formation of scales of bark, giving the surface a roughened scaly appearance.

*First Stage.*—At the very beginning only an outer layer of bark appears to be injured or changed, an inner layer next to the cambium still being alive and active and free from discoloration except that it

frequently presents a slight greenish appearance. Later a yellowish discoloration may appear, due to the development of gum within the tissue. The trunk and large limbs of all trees should be inspected carefully to detect the disease at its very first beginning. When these beginning areas are small and do not cover more than 1/4 of the circumference, the affected bark may be scraped rather deeply and the surrounding apparently unaffected bark scraped very lightly for 4 to 6 inches in all directions beyond the margin of the affected areas.

*Second Stage.*—When the disease has progressed further, so as to cover more than about 1/3 of the circumference of the entire bark on the trunk but has not yet seriously injured the wood, it may for convenience be considered to be in the second stage. At this stage the affected portion often presents a roughened surface (fig. 12).

Fresh scaling of the bark on the advancing edges continues and exudation of gum takes place at certain seasons of the year. In such cases the cure is more uncertain, but the disease may often be checked and sometimes cured by a light to medium scraping. Particular attention should be given to the advancing edges. Care must be taken not to scrape deeply enough to kill the inner layer of bark. The affected surface may then be treated with a disinfectant as previously mentioned. Six months or a year later, these should be treated again, scraping only where the disease is still active. The progress of the disease is so slow that usually one cannot discern within less than six months or a year, whether it has progressed or not.

*Third Stage.*—Where the disease has been present for a number of years (5 to 10 or more) or until a greater part of the bark of the trunk is affected and the wood underneath is killed and beginning to decay, there is little hope for a permanent recovery. A tree of this kind, however, sometimes remains surprisingly productive for a number of years, so that it becomes a question whether to replace it at once or to treat it superficially with the idea of preventing possible spread to other trees, and of taking it out later. If only a part of the branches show the disease in the second and third stages, these may be cut out entirely and the remaining part of the tree frequently inspected for further outbreaks. If the wood is just beginning to be discolored and killed, this should be chisled out and benzene-asphalt paint or other good wood protecting covering applied to the exposed surfaces. A severe cutting back of a badly affected tree may be helpful. If the trunk is too badly decayed and the entire tree appears stunted and unproductive, the tree should be dug out at once.

*Season of the Year.*—Where there is much frost hazard, bark scraped too late in the fall or during the winter months is likely to be

killed by low temperatures. Experiments at Riverside indicate that bark treated in the late spring and summer months recovers most rapidly.

*Fungicides.*—As was previously stated, the kind of fungicide employed appeared to be of minor importance in certain of our experiments. Some kind should be applied, however, to the scraped areas, as a matter of precaution. Except for the slight danger to the foliage when followed by fumigation there is nothing better than Bordeaux paste. Other substances of good fungicidal value are some of the high-boiling coal tar products such as Arrow Carbolineum, Creolineum XXX, etc. Mercuric cyanid, 1 part dissolved in 500 parts of water and 500 parts alcohol, as used for pear blight, is also an excellent disinfectant. There are many others that might be used.

For Bordeaux paste, dissolve 1 pound of bluestone (copper sulfate) in 3 quarts of water in a wooden, earthen or glass vessel and slake 2 pounds of lime in 3 quarts of water. The bluestone is most easily dissolved by suspending it in a sack at the top of the water overnight. If the bluestone is pulverized and suspended in warm water it dissolves rapidly. Good lime that is not air-slaked should be used. If covered to avoid evaporation the dissolved ingredients will keep indefinitely in separate vessels. Where the paste is being used over a number of days or weeks, just enough of the wet slaked lime and the bluestone solution should be mixed to last for one or two days. It may be applied with large whitewash brushes. Commercial Bordeaux pastes brought to equivalent strength may also be used.

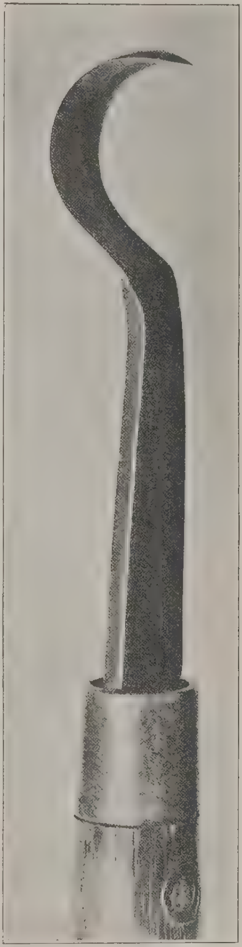

Fig. 13.—Tool for scraping the bark or for gouging out small diseased areas caused by psorosis or other bark diseases.

*Tools.*—A number of different kinds of scrapers are in use for scraping the bark. Several types devised by Mr. Culbertson of the Limoneira Company for use in the

treatment of Botrytis gummosis are shown in figure 10. A modification of one of these, first made under the direction of Dr. J. T. Barrett of the Citrus Experiment Station, is now in common use. It may be made of spring steel and consists of a curved blade sharpened on both edges and at the end and set in a wooden handle. The handle is 7½ inches long and 1¼ inches in diameter and the steel part containing the curved blade is 5½ inches long (fig. 13). These may be made by a local blacksmith or obtained through the farm advisor.

## DIPLODIA GUMMING[49]

In a former publication[50] it was stated that this form of gumming had not been seen in California, but was common in southern Florida and Cuba. Since then a Diplodia fungus similar to the Florida one has frequently been found in California especially in San Diego county associated with a gumming of large branches. A gummosis due to a Diplodia has been found recently in the Philippines also.[51] This fungus appears to be especially active in California in connection with the so-called "heart rot" following severe freezes. After the freeze of 1913 this fungus was found advancing into the yet unkilled wood of large branches which had been cut off after the freeze, resulting in frequent gum formation. The fungus advanced much more rapidly in branches whose cut ends were sealed with grafting wax than in those not so sealed. The Diplodia attack resulted indirectly in the death of areas of bark, but the fungus advanced much more rapidly in the woody tissue (fig. 14).

*Control.*—The heart rot due to Diplodia following a severe freeze is difficult to control. A non air-tight disinfectant, such as Bordeaux paste, mercuric cyanid (1 part in 1000 parts of denatured alcohol) or other non-injurious substance, should be used to disinfect the tools and cut surfaces. This treatment may be followed by the sealed covering sometime later when the wound has thoroughly dried out. If only one application is to be used, a thin substance like the higher boiling coal tar products, as Avenarius carbolineum, Arrow carbolineum, or Creolineum XXX, may be used. All parts of the tree cut back should be thoroughly whitewashed to prevent sunburning.

---

[49] Fawcett, H. S., *Diplodia natalensis* as a gum-inducing and fruit-rotting fungus. Report of Plant Pathologist, Fla. Agr. Exp. Sta. Ann. Report, 1911, pp. 61–67, 1912.

Gumming, Report of the former Plant Pathologist, Fla. Agr. Exp. Sta. Ann. Report, 1912, pp. 77–92, 1913.

[50] Fawcett, H. S., Citrus diseases of Florida and Cuba compared with those of California. Univ. of Calif. Agr. Exp. Sta. Bull. 262, p. 210, 1915.

[51] Reinking, O. A., Philippine Agriculturist, vol. 9, 123–127, 1921.

## TWIG GUMMING

A gumming and dying of a few scattered twigs, especially on naval orange trees, in the late summer or fall, is usually of minor importance. It occurs in both California and Arizona. The cause is unknown. It is characterized by sudden wilting of leaves and dying back of twigs

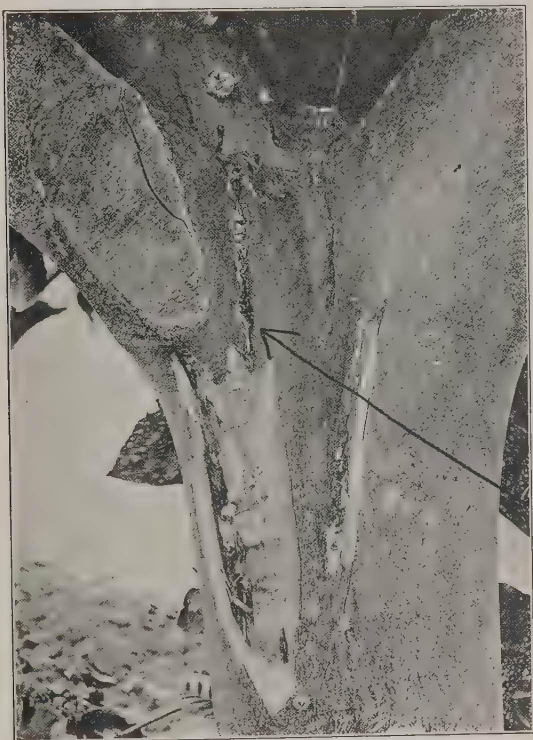

Fig. 14.—Gumming (at the point of the arrow) on lemon bark, due to *Diplodia* sp. following a severe frost injury.

or small branches to a distance of 12 to 24 inches from their tips. At the base of the dead portion the bark splits and gum oozes out in considerable quantities. It appears to occur most often after periods of hot dry weather and has been known in California for many years as a minor trouble. It is quite distinct from citrus blast though sometimes confused with the latter disease.

A somewhat similar gumming, associated with the dying back of twigs and branches but without the characteristic splitting of the bark, has frequently been noted in good sized nursery trees. Although certain organisms have been found in the lesions none of them have reproduced the disease on inoculation. These forms of twig gumming differ from twig blight caused by the cottony rot fungus, *Sclerotinia libertiana,* in the absence of a whitening or shredding of the bark and of the black sclerotia frequently formed in the bark attacked by that fungus.

Fig. 15.—Cross-section of a green orange from a tree affected with exanthema. The darked areas between the septa next to the core indicate the presence of clear gum that has taken the place of the normal tissue.

## EXANTHEMA

*Nature and Symptoms.*—Exanthema, or die-back as it is commonly called in Florida, is often classed as a gum disease although gum formation is not always a conspicuous feature. The clear gum seen in connection with exanthema exudes only from gum pockets on the twigs, or is formed internally near the center of the fruit at the angles of the segments (fig. 15). Dark excrescences and multiple buds on the branches, dying back of terminal branches, compact shortened growth and dark irregular reddish brown patches on the surface of the fruit are other symptoms.

The disease has been considered to be the result of a nutritional disturbance, but the actual cause is unknown. Localized areas in California orchards showing exanthema have frequently been noted where sheep corrals or cattle barns had been located in previous years. It has also been found in other instances to correspond to spots where the top soil had been graded off in leveling the orchard before planting. Although the use of large amounts of organic nitrogenous fertilizers, such as stable manure, dried blood and cottonseed meal have been considered to be contributing factors in inducing exanthema on some soils in Florida, these fertilizers have not been observed to encourage the disease under California conditions.

### CONTROL

In many cases in California where exanthema has been troublesome in young trees in localized areas, the trees have outgrown the trouble without any special treatment. In cases where the contributing conditions are such as may be economically removed by the grower the remedy is, of course, obvious.

Exanthema is of such minor importance in California that no study has yet been made of special methods of control. The methods used in Florida cannot be recommended for California without trial as the disease is here manifested under such widely different conditions.

## OTHER MINOR FORMS OF GUMMING

In addition to the gum diseases already discussed there frequently occur minor forms of gumming, some of which have been shown to be induced by microörganisms while other forms are brought about by insect injuries, chemical stimuli, or in certain cases by physical effects of the environment.

Most of these forms of gumming cannot be classed as definite diseases and are of minor importance commercially as compared with the preceding diseases.

### PENICILLIUM ROSEUM

Gumming due to *Penicillium roseum.* This fungus, which forms small pink tufts of hyphae and spores on the surface of lemon bark, is capable of inducing a small amount of gum exudation and death of small areas of bark, as has been shown by inoculations with pure cultures. It has been found as a secondary fungus associated with Botrytis gummosis and shell bark on lemon trunks, mostly in the moister coastal sections of California.

### FUSARIUM

Many species of this genus of fungus produce pinkish to red pustules or masses of spores within the surface layer of dead bark of lemon trees. In general appearance and color these red masses look to the unaided eye much like those of *Penicillium roseum.* This fungus also has been shown to be capable of inducing the formation of a small amount of gum, and of causing a very limited amount of injury to bark tissue adjoining a wound when inserted into cuts on sound tissue, but did not produce definite diseased lesions. It has frequently been found associated with brown rot (Pythiacystis) gummosis and appears to be capable of increasing the severity of this gummosis when associated with *Pythiacystis citrophthora* (as has previously been mentioned under "brown rot gummosis") but when acting alone, Fusarium appears to be of minor importance in gummosis. It should be stated, however, that Barrett[52] has found species of Fusarium constantly associated with the 'dry root rot' of citrus in connection with which considerable gumming is frequently noted. Although the disease has not been reproduced by inoculation, this fungus is thought to be an important factor in the development of dry root rot of citrus.

### ALTERNARIA

A species of Alternaria similar to *Alternaria citri* has very frequently been found in bark tissue associated with minor forms of gumming on lemon trees. Inoculation with pure cultures has shown that it may sometimes induce slight gum exudation and very slight injury to tissue adjacent to cuts into which spores were inserted. Small green immature navel oranges affected with black rot frequently show gum exudation at the navel cavity apparently due to the presence of *Alternaria citri.*

Gumming due to *Bacterium citriputeale* C. O. Smith. If, during the season for citrus blast and black pit attack, the weather becomes warmer than usual, small drops of gum are apt to form at the edges of the twig lesions caused by the citrus blast bacterium. Slight gumming has been noted also on cuttings inoculated with this bacterium and held in moist chambers over a free water surface at constant temperatures of 80° and 93.4°F. (30° and 34°C.), but not at temperatures below this. Control punctures produced no gum. Large light-green lemon fruits also develop gum by inoculation with the same organism under the same conditions, but not in the uninoculated punctures.

[52] Barrett, J. T., Dry root rot. Calif. Citrus Inst., First Ann. Rept. 1919–1920, p. 157, 1920.

It is probable that various other fungi are responsible for minor forms of gumming in citrus. Observation has indicated that under certain conditions *Armillaria mellea, Schizophyllus commune* and other wood rotting fungi are minor agents in bringing about small gum exudations.

## GUMMING ASSOCIATED WITH INSECT INJURIES

The injuries to citrus made by a number of insects are frequently followed by gumming, usually slight in amount. Small drops of gum may form on fruit at injuries produced by the orange tortrix (*Tortrix citrana*), and on small tree trunks and limbs from grasshopper, katydid and other insect injuries. Gumming has frequently been noted on twigs badly infested with the California red scale. To what extent this gumming may be due to secretions of the insects or to the entrance of microörganisms at the time of injury is uncertain. Our negative results from mechanical injuries to citrus kept sterile and free from chemical stimuli would indicate that this gumming was probably not due to the injury or wound in itself.

## GUMMING ASSOCIATED WITH CHEMICAL STIMULI

Among the chemical stimuli that have been seen to result in gum formation occasionally in citrus orchards may be mentioned: (1) liquid hydrocyanic acid spilled on the soil near the roots of trees; (2) hydrocyanic acid gas used in fumigation; (3) spray mixtures containing copper sulfate not properly neutralized with lime or containing other toxic substances; (4) a poison containing arsenic in contact with the bark, etc.

Hydrocyanic acid coming in contact with a large main root usually causes the death of a strip of limited section of the bark on the trunk, and even on the limbs and branches leading up from this portion of the trunk. This frequently results in considerable gumming adjacent to the killed strip and is sometimes mistaken for a definite gum disease. Under some conditions the shock to citrus trees produced by fumigation with hydrocyanic acid gas appears to be responsible for initiating gumming on the tree trunks of orange trees especially. The pressure in small gum pockets formed near the cambium produces small rifts in the bark through which the gum exudes in small drops, sometimes in numerous places on the trunk. Sometimes coils or strings of gum will be pushed out of small openings one to two weeks after fumigation. Such gumming is usually temporary and the places where the gum has formed quickly close up and fill with new tissue without noticeable injury to the tree.

Copper sulfate solution if spilled on the soil over a root will act in much the same way as the hydrocyanic acid in killing strips of bark and resulting in gumming.

Ant poisons containing arsenic when allowed to leak out of the containers frequently kill patches of bark and set up gumming.

### PHYSICAL EFFECTS OF THE ENVIRONMENT

Physical effects do not appear to be as a rule more than contributing conditions for gumming in citrus under California conditions, other stimuli acting as the immediate cause.

*Mechanical Injuries.*—The writer has not been able to induce gum exudation on healthy citrus trees by mechanical injuries alone, provided the injuried portions are kept clean and reasonably free from contamination with microörganisms or unusual chemical substances. The following kinds of wounds were made: cuts vertically or horizontally through the bark, augur holes with and without glass or wooden plugs, bruises made by heavy and light blows from a blacksmith's hammer, long horizontal and vertical slits through the bark areas, of bark cut away, etc. All such injuries kept clean, healed in the usual way without gumming. When purposely infected with *Botrytis cinerea* or other injurious fungi, however, gumming resulted.

*Burning and Freezing.*—Sunburning and freezing are not important factors in themselves in initiating gum formation in citrus, although they do act as contributing conditions by allowing the entrance of organisms such as *Botrytis cinerea, Sclerotinia libertiana* or other fungi which, after becoming established in the injured tissue, may advance rapidly and induce gumming in tissue apparently sound. Freezing and sunburning often get credit for initiating the gumming when they have merely opened up the way for its initiation by other agencies.

## SUMMARY

For the sake of brevity this summary deals with average conditions. Allowance must therefore be made for variations in treatment for unusual or abnormal conditions. Consult the discussions in the text for more detailed statements.

*Pythiacystis (Brown Rot) Gummosis.*—Prevented by pulling the soil away from the base of the tree trunk until the tops of the first main roots are exposed; by keeping the soil next to the trunk from becoming excessively wet; by avoiding injuries to the bark; by painting the trunks with fungicide such as Bordeaux paste, and by using

sour-orange stocks budded high for all new plantings, especially on heavy clay soils. Treated, when not too far gone, by cutting away the invaded killed bark, but not necessarily the outer gummous zone, and painting the wound with a suitable fungicide; by scraping away any outer layers of dead bark; by painting exposed portions of wood (after healing of edges begins) with benzine-asphalt paint or other suitable covering; by cutting back the tops on trees severely affected; by inarching or bridge grafting in certain cases.

*Botrytis and Sclerotinia Gummosis.*—Prevented by the same methods as to soil, water, injuries, fungicides and use of sour-orange stocks as in case of previous disease. Treated by cutting out the dead bark to the wood and by scraping off only the outer bark beyond this where the inner layer is not killed, and by painting with fungicide as in the previous disease.

*Psorosis (Scaly Bark) of Orange Trees.*—Methods of prevention not definitely known. Treated by scraping away the outer affected bark of lesions in the first and second stages, scraping lightly the bark not yet visibly affected to a distance of 6 to 8 inches beyond the lesion in each direction and applying Bordeaux paste or other suitable fungicides; by cutting out certain badly affected limbs altogether; by eliminating certain of the worst trees in the third stage of the disease or cutting them off below the diseased part where this is possible. Treatment must vary much according to the stage of the disease. (See discussion of various stages.)

*Diplodia Gumming and Twig Gumming.*—Treated by eliminating the parts affected and by treating cuts with fungicide followed by paint where wounds are large.

*Exanthema.*—Little is known as to its real cause, and no one definite method of prevention or control can be suggested for California conditions except to eliminate certain supposed contributing conditions where this is possible. (See previous discussion.)

*Minor Forms of Gumming.*—Not many of these are sufficiently important to require special attention either as to prevention of treatment. Where they are due to organisms most of the same principles apply as are given for the previous diseases. Some forms are dependent upon conditions that cannot be controlled but recovery often follows a change in the contributing conditions.

## STATION PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION

### BULLETINS

No.

253. Irrigation and Soil Conditions in the Sierra Nevada Foothills, California.
261. Melaxuma of the Walnut, "Juglans regia."
262. Citrus Diseases of Florida and Cuba Compared with those of California.
263. Size Grades for Ripe Olives.
268. Growing and Grafting Olive Seedlings.
270. A Comparison of Annual Cropping, Biennial Cropping, and Green Manures on the Yield of Wheat.
273. Preliminary Report on Kearney Vineyard Experimental Drain.
275. The Cultivation of Belladonna in California.
276. The Pomegranate.
278. Grain Sorghums.
279. Irrigation of Rice in California.
280. Irrigation of Alfalfa in the Sacramento Valley.
283. The Olive Insects of California.
285. The Milk Goat in California.
286. Commercial Fertilizers.
287. Vinegar from Waste Fruits.
294. Bean Culture in California.
297. The Almond in California.
298. Seedless Raisin Grapes.
299. The Use of Lumber on California Farms.
304. A study on the Effects of Freezes on Citrus in California.
308. I. Fumigation with Liquid Hydrocyanic Acid. II. Physical and Chemical Properties of Liquid Hydrocyanic Acid.
312. Mariout Barley.
313. Pruning Young Deciduous Fruit Trees.
316. The Kaki or Oriental Persimmon.
317. Selections of Stocks in Citrus Propagation.
319. Caprifigs and Caprification.
321. Commercial Production of Grape Syrup.
324. Storage of Perishable Fruit at Freezing Temperatures.
325. Rice Irrigation Measurements and Experiments in Sacramento Valley, 1914–1919.
328. Prune Growing in California.
331. Phylloxera-Resistant Stocks.
332. Walnut Culture in California.
334. Preliminary Volume Tables for Second-Growth Redwoods.
335. Cocoanut Meal as a Feed for Dairy Cows and Other Livestock.
336. The Preparation of Nicotine Dust as an Insecticide.
337. Some Factors of Dehydrater Efficiency.
339. The Relative Cost of Making Logs from Small and Large Timber.
340. Control of the Pocket Gopher in California.
341. Studies on Irrigation of Citrus Groves.
342. Hog Feeding Experiments.
343. Cheese Pests and Their Control.
344. Cold Storage as an Aid to the Marketing of Plums.
345. Fertilizer Experiments with Citrus Trees.
346. Almond Pollination.
347. The Control of Red Spiders in Deciduous Orchards.
348. Pruning Young Olive Trees.
349. A Study of Sidedraft and Tractor Hitches.
350. Agriculture in Cut-over Redwood Lands.
351. California State Dairy Cow Competition.
352. Further Experiments in Plum Pollination.
353. Bovine Infectious Abortion.
354. Results of Rice Experiments in 1922.
355. The Peach Twig Borer.
356. Observations on Some Rice Weeds in California.
357. A Self-mixing Dusting Machine for Applying Dry Insecticides and Fungicides.
358. Black Measles, Water Berries, and Related Vine Troubles.
359. Fruit Beverage Investigations.
360. Gum Diseases of Citrus Trees in California.

### CIRCULARS

No.

70. Observations on the Status of Corn Growing in California.
82. The Common Ground Squirrel of California.
87. Alfalfa.
110. Green Manuring in California.
111. The Use of Lime and Gypsum on California Soils.
113. Correspondence Courses in Agriculture.
117. The Selection and Cost of a Small Pumping Plant.
127. House Fumigation.
136. *Melilotus indica* as a Green-Manure Crop for California.
144. Oidium or Powdery Mildew of the Vine.
148. "Lungworms."
151. Feeding and Management of Hogs.
152. Some Observations on the Bulk Handling of Grain in California.
155. Bovine Tuberculosis.
157. Control of the Pear Scab.
159. Agriculture in the Imperial Valley.
160. Lettuce Growing in California.
161. Potatoes in California.
165. Fundamentals of Sugar Beet Culture under California Conditions.
166. The Country Farm Bureau.
167. Feeding Stuffs of Minor Importance.
169. The 1918 Grain Crop.
170. Fertilizing California Soils for the 1918 Crop.
172. Wheat Culture.
173. The Construction of the Wood-Hoop Silo.
174. Farm Drainage Methods.
175. Progress Report on the Marketing and Distribution of Milk.
178. The Packing of Apples in California.
179. Factors of Importance in Producing Milk of Low Bacterial Count.
182. Extending the Area of Irrigated Wheat in California for 1918.
183. Infectious Abortion in Cows.
184. A Flock of Sheep on the Farm.
188. Lambing Sheds.
190. Agriculture Clubs in California.
193. A Study of Farm Labor in California.
198. Syrup from Sweet Sorghum.
199. Onion Growing in California.
201. Helpful Hints to Hog Raisers.
202. County Organizations for Rural Fire Control.

| No. | |
|---|---|
| 203. | Peat as a Manure Substitute. |
| 205. | Blackleg. |
| 206. | Jack Cheese. |
| 208. | Summary of the Annual Reports of the Farm Advisors of California. |
| 209. | The Function of the Farm Bureau. |
| 210. | Suggestions to the Settler in California. |
| 212. | Salvaging Rain-Damaged Prunes. |
| 214. | Seed Treatment for the Prevention of Cereal Smuts. |
| 215. | Feeding Dairy Cows in California. |
| 217. | Methods for Marketing Vegetables in California. |
| 218. | Advanced Registry Testing of Dairy Cows. |
| 219. | The Present Status of Alkali. |
| 224. | Control of the Brown Apricot Scale and the Italian Pear Scale on Deciduous Fruit Trees. |
| 225. | Propagation of Vines. |
| 228. | Vineyard Irrigation in Arid Climates. |
| 230. | Testing Milk, Cream, and Skim Milk for Butterfat. |
| 232. | Harvesting and Handling California Cherries for Eastern Shipment. |
| 233. | Artificial Incubation. |
| 234. | Winter Injury to Young Walnut Trees during 1921–22. |
| 235. | Soil Analysis and Soil and Plant Interrelations. |
| 236. | The Common Hawks and Owls of California from the Standpoint of the Rancher. |

| No. | |
|---|---|
| 237. | Directions for the Tanning and Dressing of Furs. |
| 238. | The Apricot in California. |
| 239. | Harvesting and Handling Apricots and Plums for Eastern Shipment. |
| 240. | Harvesting and Handling Pears for Eastern Shipment. |
| 241. | Harvesting and Handling Peaches for Eastern Shipment. |
| 242. | Poultry Feeding. |
| 244. | Central Wire Bracing for Fruit Trees. |
| 245. | Vine Pruning Systems. |
| 246. | Desirable Qualities of California Barley for Export. |
| 247. | Colonization and Rural Development. |
| 248. | Some Common Errors in Vine Pruning and Their Remedies. |
| 249. | Replacing Missing Vines. |
| 250. | Measurement of Irrigation Water on the Farm. |
| 251. | Recommendations Concerning the Common Diseases and Parasites of Poultry in California. |
| 252. | Supports for Vines. |
| 253. | Vineyard Plans. |
| 254. | The Use of Artificial Light to Increase Winter Egg Production. |
| 255. | Leguminous Plants as Organic Fertilizer in California Agriculture. |
| 256. | The Control of Wild Morning Glory. |
| 257. | The Small-Seeded Horse Bean. |
| 258. | Thinning Deciduous Fruits. |
| 259. | Pear By-products. |